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Exploring Metacognition, Multitasking and Test Performance in a Lecture Context

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By

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Abstract

Multitasking has become more prevalent with recent advancements in technology (Judd, 2014; Junco & Cotten, 2012). Many self-report studies, and the few available experimental manipulations, consistently indicate that media multitasking is related to decrements in learning. The present study extends the current literature by explicitly documenting students' responses to media-based interruptions to learning. The current study also documents other behaviours students engage in that may or may not be related to multitasking when technology is available during lectures. In addition, the study explores the role of metacognition as a contributor to learning in a media-rich educational setting. In total, 118 Introductory Psychology students attended a 40-minute lecture and were assigned to one of three conditions: Facebook multitasking, multitasking choice, and no-technology control. Prior to participating, they completed a measure of metacognitive awareness and perceptions toward technology. After the lecture, they were tested for content knowledge, metacognitive awareness, and perceptions toward multitasking. A subsample of students in the technology conditions was video recorded and asked to identify their actions and thoughts at key times during the lecture. Qualitative coding of these interviews yielded seven overall themes dealing with multitasking behaviours and seven themes specific to learning behaviours. Overall, there was a trend towards increasing metacognition over time, with some aspects such as monitoring appearing in both the traditional measure of metacognitive awareness and in the students' thematic summaries. Student performance was lower for content where prompts/messages were sent to the learners, suggesting that prompts and messages are problematic distractions for learning. Overall, the present study documents what multitasking looks like in today's students, and identifies factors that do or do not influence multitasking behaviours and outcomes.

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Effective learning in higher education depends on learner skills, pedagogical effectiveness and learning tools. Students in higher education classrooms today are equipped with a diverse array of technologies, which they expect to use as part of their learning experience (Bowman, Waite, & Levine, 2015). Likewise, instructors are increasingly provided with technologies to enhance learning experiences and to provide diversity in instructional opportunities (Bowman et al., 2015). To date there is controversy regarding the pedagogical efficacy of using technologies, with some contexts and uses supporting learning gains (Bowman et al., 2015; Junco, 2012a; Junco, 2012b) and others inviting distraction and learning losses (Bowman et al., 2015; Junco, 2012c; Junco, 2015; Junco & Cotten, 2011; Junco & Cotten, 2012; Rosen, Lim, Carrier, & Cheever, 2011; Wood et al., 2012). Although the pedagogical underpinnings of instruction are critical to effective instruction, learner use of technologies often occurs independent of pedagogical design. However, the significant presence of technologies in the classroom warrants further investigation from the perspective of learners even when pedagogy is not the main issue. In the present study, the impact of learner skills and learning tools in a media-rich context is explored. Specifically, metacognitive skills of learners are explored in the context of exposure to media while attending lectures. Thus, in a real-time lecture context, the present study will assess metacognitive skills, perceptions involved in predicting performance when multitasking, and natural classroom participation.

Metacognitive Skills

Metacognition refers to a broad set of skills that allow learners to direct, monitor and assess the acquisition, retention and application of new and learned knowledge and skills (Schraw, 1998). Conceptualizations of metacognition generally share two fundamental components: knowledge of cognition and regulation of cognition. The former involves people's awareness and knowledge of their own cognition and cognition in general. The latter refers to the ability to exert attention and control to regulate their cognitions (Schraw, 1998).

Awareness and knowledge of one's cognition is multifaceted. It encompasses declarative, procedural, and conditional knowledge. Declarative and procedural knowledge distinguish between knowing "what" and knowing "how." Specifically, declarative knowledge involves knowing one's own cognition and the factors affecting it (Schraw, 1998). Individuals identified as successful learners have high declarative knowledge (Schneider & Pressley, 1989). Procedural knowledge is knowing the method of performing tasks. Generally, procedural knowledge is observed as heuristics and strategies. Those who are high in procedural knowledge process information faster, have larger strategic repertoires (ranging from mnemonic to elaboration), and use these repertoires more effectively than those who are low in procedural knowledge (Schraw, 1998). Conditional knowledge involves mechanisms to coordinate between an individual's own knowledge and what s/he can apply in a specific context (Schraw, 1998). Thus, conditional knowledge allows learners to determine "why" and "when" to put declarative and procedural knowledge into effect. Conditional knowledge requires learners to know the difference between declarative and procedural knowledge and to use each accordingly and effectively (Garner, 1990; Reynolds, 1992). High conditional knowledge allows learners to adapt to situational demands (Schraw, 1998).

Regulation of cognition is also multifaceted and includes skills that help control one's cognitive processes and yield learning gains. Individuals high in regulation demonstrate "better use of attentional resources and existing strategies, and greater awareness of comprehension breakdowns." (Schraw, 1998, pg. 114). Three skills inherent in regulation are planning, monitoring, and evaluating. Planning refers to contexts where learners must choose among strategies and allocate appropriate resources correctly to maximize learning. Planning occurs at the onset of a task. For example, prior to lectures, skilled students might make predictions about upcoming content, decide which strategies might facilitate learning effectively depending on the context of the class (e.g., lecture versus seminar), and then decide how much time they might need to prepare for the class or study after the class. Monitoring involves ongoing evaluation to ensure comprehension of task performance. For example, skilled learners often engage in self-testing or review to ensure comprehension of text when reading. Evaluating involves assessing the outcomes associated with given tasks and the effectiveness of methods selected for task completion. Evaluation allows opportunities to re-consider initial goals and employ refinements as needed.

Together, the components of metacognition, knowledge of cognition and regulation of cognition, allow learners to know what they do and do not know and how to best approach learning tasks. Although these skills can be taught, they typically develop throughout childhood and into early adolescence (Waters & Schneider, 2010).

Metacognitive Development

Metacognition develops over the life span. One of the earliest developments that reflect metacognitive development is the use of words like 'think' and 'know' at age three. This developmental change reflects that children are beginning to gain awareness of cognitive functions and the difference between those functions. For example, children come to understand the difference between estimating (i.e., "I think") and being sure about a topic (i.e., "I know"; Flavell, 1999). Another important milestone is the development of theory of mind, which appears around ages four to five. At this time, children begin to understand that others' thoughts and experiences may be different from their own, and thoughts of others could be right or wrong (Kuhn, 2000). Children also begin to become aware of a diversity of strategies that can be used to help acquire, organize or remember information. However, at this point in development, children typically fail to spontaneously execute or implement these strategies (e.g., Schneider & Pressley, 1989; Waters & Andreassen, 1983). By ages 11 to 12, pre-adolescents begin to think about abstract concepts in a scientific and "higher-order" manner. In addition, pre-adolescents demonstrate greater fluency in foundational components of metacognition. For example, pre-adolescents begin to execute strategies independently without the traditional deficiencies in production and utilization demonstrated earlier in development (e.g., Schneider & Pressley, 1989; Waters & Andreassen, 1983). Enhancements in higher order thinking and metacognitive skills continue to develop throughout the adolescent years (Schraw, 1998).

Metacognitive Skills and Learning

Learning and metacognition share a reciprocal relationship. Specifically, effective and efficient learning requires metacognitive skills; however, the act of learning, which involves planning, execution of strategies, and monitoring provides an opportunity to practice and enhance metacognitive skills (Schraw, 1998). Using metacognitive skills to learn can benefit processing speed, automaticity, building a repertoire of strategies, effective use of strategies, allocation of resources, learning, and performance. Processing speed involves the rate at which learners attend, perceive, understand, change, use and store information. "Good" learners typically exhibit faster processing speed. Automaticity occurs when information is processed and takes effect without intentional control or effort (Schneider & Chein, 2003). Automaticity, as the name implies, permits processing to occur effortlessly and efficiently, as well as facilitating easy access to acquired knowledge. Automaticity is also related to strategy use. Individuals high in metacognition not only have large and varied strategic repertoires but they execute strategies fluently and automatically as required by the situation (Schraw, 1998). Similarly, greater proficiency in each of these domains positively impacts learning.

Learning requires fluency among the many components and skills of metacognition. In addition, the nature of the task, familiar or unfamiliar, can effect the learner and learning. For example, the more declarative knowledge learners have, the better learners they tend to be. “Good” learners have more domain knowledge[1] and greater knowledge about different aspects of memory. Specifically, the importance of domain knowledge is examined within the context of the expert-novice literature. Expertise improves performance, organization of knowledge (structure), problem solving skills and transfer of skills to other tasks (Bédard & Chi, 1992). For example, chess experts can recall the exact location of each piece in an ongoing game (Chase & Simon, 1973), children can perform better than adults on tasks for which they have high domain knowledge (i.e., chess; Chi 1978), and baseball experts recognize more information from a text passage about baseball than baseball novices (Bédard & Chi, 1992).

It is expected that experts have more knowledge about their area of expertise than novices in the area (e.g., how to best approach a task and learning strategies), but they also have ‘higher-order organization’ of their knowledge that makes knowledge more readily accessible and ready to use when accessed. This vast and organized knowledge base allows experts to move forward in a more strategic way on a given task. For example, a physics question may describe a real-life event that can be pictured in the mind (so everyone at all levels can understand), however novices and experts will likely approach the problem in different ways. Experts will first develop a representation of the question by identifying and defining the important features of the problem

[1] Although some literature separates specific and general domain knowledge, the present paper encompasses both of these terms when referencing domain knowledge.

in terms of the rules of physics, and then attempt to answer the question [e.g., “block = mass” and “suspension = gravity(g)]”. Novices will also want to develop a representation of the problem, but will typically categorize the features of the questions in a literal way (e.g., block is block and suspension is suspension). Novices’ attempts to answer the same question as the experts will likely take much longer if they are successful at all (Bédard & Chi, 1992).

Organizations of knowledge (i.e., schemata) from different learning experiences are stored in interrelated networks. These networks serve an important function in comprehending new material by linking new information to old information. When people encounter salient cues related to their networks in the environment, relevant schemata become “activated,” allowing them access to all, or part, of the network. This process of memory storage and retrieval is known as the cognitive schema theory (Anderson & Pearson, 1984). Consistent with the cognitive schema theory, experts have many and strong links between concepts within their domain, easing and automatizing the process of making connections and retrieving information. Novices (those with low domain knowledge) have fewer and weaker links.

A multitude of studies have examined the impact of prior knowledge or ‘expertise’ for finding and retrieving information. Within the diverse literature available, a series of studies have examined the ability of learners to find and extract needed information in either traditional textbook contexts or in online contexts. For example, Symons and Pressley (1993) demonstrated that individuals with low domain knowledge were less efficient and effective at finding information in a textbook than those with high domain knowledge. The key difference in speed was not in getting within close proximity of the target material, but in identifying the needed information.

Subsequently, Willoughby, Anderson, Wood, Mueller, and Ross (2009) compared participants with low and high domain knowledge in an Internet search context. They asked participants to write two essays, one relative to a topic for which they had high expertise (expert) and one relative to a topic for which they had little domain knowledge (novice). In addition, half the expert and novice participants had an opportunity to search the Internet to find information prior to completing their essay and the other half did not. They found that providing students with an opportunity to search the Internet prior to writing the essay only improved essay content for topics associated with high domain knowledge. Content of essays from the non-search control groups did not differ from the search groups for topics related to low-domain knowledge. This finding suggests that high domain knowledge is key in acquiring and using information found while searching the internet.

Most recently, researchers (Wood, et al., 2016) contrasted the relative impact of expertise in search skills (high versus low) and expertise in domain knowledge (high versus low) for finding information using the Internet. The combination of expertise in search strategies and high domain knowledge led to the most efficient searches. These participants visited the fewest sites and were less likely to re-visit sites in their search to acquire accurate information. In addition, differences in the quality of sites visited were associated with search expertise and domain knowledge. Specifically, greater search expertise was associated with searches accessing sites with more accurate and more credible content while greater domain knowledge was associated with accessing sites rated more thorough. Together these studies demonstrate the key roles domain knowledge and expertise play in learning contexts.

Media Use in the Classroom

The increasing prevalence of portable, affordable and powerful digital technologies, such as laptops, tablets, and smartphones, has encouraged greater uptake of technologies both within and beyond the educational environment (Courage et al., 2015). Evidence of the potential for harnessing these portable technologies as learning tools is present in research and reports of all levels of education (Bowman et al., 2015; Wood & Zivcakova, 2015). For example, social network platforms such as Facebook™ initially entered the classroom context informally as a means for sharing logistical information (e.g., time of classes, assignment details) as well as engaging in intellectual discussions, collaborations and idea sharing (Bosch, 2009; Madge, Meek, Wellens & Hooley, 2009; Ractham & Kaewkitipong, 2012; Selwyn, 2009). Subsequently, these informal additions became formalized when educators integrated the use of social networks within the classroom (Bosch, 2009; Ractham & Kaewkitipong, 2012; Roblyer et al., 2010) to enhance social connections among students (e.g., connecting younger and older students, promoting collaboration in the classroom and peer support; Arnold & Paulus, 2010; Bosch, 2009; Selwyn 2009), increase participation and motivation (e.g., asking questions, offering input into class material in advance; Bosch, 2009; Mazer, Murphy & Simonds, 2007), and promote development in some skill areas (e.g., Blattner & Fiori, 2009).

In the higher education context, instructors express mixed opinions regarding the use of mobile technologies within the classroom. On one hand, there is evidence that integrating these technologies can provide interesting and engaging instructional tools (Junco, 2012b) as well as promote learning (Junco, 2012a). On the other hand, these tools are associated with increased distraction and decrements in learning and academic performance when students use them for off-task activities (Junco, 2012c; Junco, 2015; Junco & Cotten, 2011; Junco & Cotten, 2012; Rosen et al., 2011; Wood et al., 2012).

The Roots of Multitasking

Our current understanding of multitasking evolved from both computer science and cognitive psychology. Each of these fields focused on different aspects of the phenomenon. The field of computer science has influenced the domain of multitasking both in theory and in terminology (see Cardoso-Leite, Green, & Bavelier, 2015). With respect to terminology, four terms have transferred between computer science models and psychological models involving human cognition. Two terms, serial and parallel, describe the timing of processing in computer models. Serial processing occurs when a series of tasks are completed one at a time in sequence. Parallel processing allows for multiple tasks to be completed simultaneously or relatively simultaneously. The two remaining terms are multiprocessing and multitasking. Multiprocessing involves the ability to run multiple tasks at one time while multitasking involves rapid switching between tasks in order to perform multiple tasks. In the educational literature involving multitasking, the term 'multitasking' is typically used to reflect something different than what is captured in the computer science literature. Specifically, the term 'multitasking' is used when the computer science term regarding' multiprocessing' is actually what is being suggested. Computer programs can rapidly perform more than one command simultaneously. However, in reality a single processing unit can only process one task at a time. When a single processing unit is required to perform multiple tasks, the single processing unit rapidly switches between tasks. This activity is known as 'multitasking'. This is different than 'multiprocessing' where more than one processing unit is present and each processing unit performs one task at a time, but in parallel, allowing several tasks to be completed simultaneously. Thus, the term 'multitasking' when used in psychological and educational literatures, similar to the present study, typically denotes multiple tasks being completed at one time (i.e., multiprocessing).

Both serial and parallel processing types exist in humans, however the nature of the task determines which type of processing is most effective and efficient. Humans can engage in effective multiprocessing for simple, easy to perform tasks. In these cases, multiple stimuli can be processed in parallel. For example, for most cooks stirring and checking on soup in a pot while engaging in casual conversation with a friend would be easy. Both acts draw on different cognitive resources (i.e., visual processes and motor movements versus verbal and auditory processes). In addition, stirring the soup is an automatized activity requiring little cognitive resources. Once a task becomes complex, multitasking comes into play and at that point individuals switch back and forth between tasks. For example, a new recipe using unfamiliar ingredients or an unfamiliar stove might require more attention to ensure that the consistency, temperature and taste of the soup is as desired. This might be reflected by pauses in the conversation while the cook checks on progress. In this case, cooking the soup has become more demanding, it requires more cognitive resources taking attention away from other tasks, such as the conversation, that may be taxing cognitive resources at that time. When multitasking, the interval when switching occurs causes a disruption or a delay which is often referred to as a "bottleneck" or a psychological refractory period (PRP; see Cardoso-Leite et al., 2015).

Even for what appear to be simple tasks (e.g., pressing a key following a tone) humans may need to move from parallel to serial processing (Telford, 1931). When done simultaneously or relatively simultaneously, psychological refractory period tasks are completed in a shorter amount of time, than when they are done serially and in isolation from one another. However, this is only true when the tasks are easy, but not when they are difficult to perform. Specifically, in the early stages, perceptual stimuli tend to be performed through multiprocessing (for a review see Nassi & Callaway, 2009) and more challenging ‘executive’ tasks tend to be performed through multitasking (Pashler, 2000).

The Role of Attention in Multitasking

Although common conceptions of multitasking typically involve doing two or more tasks simultaneously, theoretical understandings are more diverse. Multitasking can mean engaging in more than one task concurrently (i.e., dual task), rapidly switching between one or more tasks, or partially attending to one stimulus and more fully attending to another (Courage et al., 2015; Wood & Zivcakova, 2015).

Psychological approaches to the study of multitasking address the issue of attention. Attention is viewed as a pooled resource, and individuals use proportions of this pool depending on the difficulty of the task (Pashler, 1994). If the task is not stimulating, challenging, or demanding, a larger proportion of the pool of attention will be available for other tasks. When tasks are difficult or demanding, little available attention can be allocated to other tasks. Thus, attentional resources are constrained by the types of tasks being performed. Because multitasking involves more than one task, it is expected that the resources needed to perform two tasks will be greater than when completing one. In addition, multitasking is expected to be more difficult to achieve and to produce greater decrements in performance when challenging tasks are involved or when the tasks compete for similar resources. For example, multitasking can be especially detrimental when same-modality tasks are involved (Carrier, Rosen, Cheever, & Lim, 2015). How attention is directed impacts what types of decrements are expected to occur.

Dual-task performance occurs when two tasks are attended to or engaged in simultaneously (i.e., parallel processing). Dual-task interference occurs when the completion time for either or both tasks increases, there is a delay in one of the tasks, and/or an error is made on either or both tasks. There are several explanations for interference. First is the "all-or-none central processing bottleneck" (Courage et al., 2015, pg. 8) where only one task can be performed at a time and therefore the secondary task is delayed, known as the psychological refractory period (Cardoso-Leite et al., 2015). Subsequent research has argued against this understanding, suggesting that interference is not necessarily a product of dual-tasking. Rather, if specific conditions are met, it is possible that multitasking can occur with little or no interference (Meyer & Kiernas, 1997b). Specifically, it is argued that people may be able to perform tasks simultaneously without decrements in performance if the following conditions are met: (1) tasks are given equal priority, (2) are performed quickly, (3) use different perceptual and motor processes, (4) do not constrain "the temporal relations or serial order among responses" (Courage et al., 2015, pg. 9), (5) and are well practiced (Meyer and Kiernas,1997b).

A second explanation, which is closer to the notion of everyday multitasking, is the "central capacity sharing model" (Courage et al., 2015). This model suggests that two tasks can be performed at the same time, for example, talking while driving. However, when one of the tasks requires more resources, resource allocation can be adjusted to meet priorities. For example, a sudden increase in traffic requires greater attention, at that point the driver may pause conversation until traffic dies down to avoid a possibly fatal accident.

Rapid task-switching involves alternately attending to two or more tasks. Experiments examining rapid task-switching most often result in a 'switch cost' (Courage et al., 2015). One explanation for this cost is referred to as task-set reconfiguration (TSR). A mental task set refers to the organization of task-relevant information (e.g., purpose of task) and the preparation of corresponding cognitive resources and processes (e.g., mental representations). When switching back and forth between tasks, people reconfigure their mental task sets to be able to perform the next task. This phenomenon is known as the TSR. The cost associated with TSR occurs because it takes time to shift from the current mental task set to the previous mental task set and recall the purpose and procedure associated with that task (Courage et al., 2015). An alternate reason for the switch cost, called task-set inertia, is that the features of the previous task interfere with the current task (Courage et al., 2015).

These theoretical considerations of multitasking have typically been examined in highly experimental, highly simplified contexts. Current models of multitasking, however, are trying to explain complex divisions of attention combined with motivation, attitudes, and other individual difference variables in the context of a media-rich world.

Multitasking and Education

The growing developments of technology with respect to functionality, efficiency, ease, and convenience is concurrent with a drastic increase of multitasking, particularly in media use. For example, a 35% increase in media multitasking in one year was reported as early as 2010 (Nielsen, 2010). As technologies have evolved from 2010 to the present and become increasingly mobile and powerful, and educators have introduced them into classrooms, concerns about multitasking in educational contexts have become more prevalent in the literature.

Multitasking, as it is understood in the educational literature, adopts some of the conceptualizations introduced in the computer science literature but may use different terminology. For example, Salvucci and colleagues introduced the idea of threaded cognition to explain the events and outcomes associated with multitasking (Salvucci & Taatgen, 2008; Salvucci & Taatgen, 2011). Threaded cognition depicts each thought as a thread. The more thought components that a task has, the more threads it has. For example, if navigating is represented by one thread, then driving is represented by many threads that work to achieve the more complex and encompassing goal of driving (Courage et al., 2015). Similarly, learning from lectures is a complex task comprised of multiple threads (e.g., listening, note-taking). Threaded cognition explains interference caused by task switching and dual task performance (Carrier et al., 2015). This concept of response cost is similar to the refractory period in impact, as described in earlier models presented in the computer science and attention literatures. This becomes particularly interesting in educational contexts when there are both relevant and irrelevant events and information that can attract the attention of students. For example, students can attend to information in the environment which is specific and relevant to the task at hand (i.e., on-task events) or the student may attend to information that is not relevant to the learning task (i.e., off-task events). In many cases on-task and off-task events compete for attention. That is, when someone engages in off-task multitasking with media while attending to lectures, there is a cost to processing when the individual switches from the media to the lecture and from the lecture to the media. Such behaviours would be expected to result in decrements or slowing in learning (e.g., Courage et al., 2015).

Studies have repeatedly shown that multitasking is detrimental to performance and learning in many contexts. Although much of the initial work on multitasking was based on self-report information, more recent accounts have directly examined multitasking and learning outcomes (Junco, 2013). For example, Wood and colleagues (2012) found that multitasking decreases memory performance on a quiz assessing material from a real-time lecture. Specifically, off-task use of Facebook and MSN messaging were especially detrimental to performance when compared to text and e-mail messaging and on-task and paper and pencil note-taking. The distraction caused by the abundance and diversity of activities offered on a single platform may be the main reason that leads to such detriments (Junco, 2015; Junco &

Cotten, 2011; Nosko, Wood, & Molema, 2010). Another proposed explanation for similar findings is the time displacement hypothesis (van der Schuur, Baumgartner, Sumter, & Valkenburg, 2015). It is thought that students spend more time on social media than school work, possibly taking away from time originally scheduled for school work. As a result, they perform poorly on academic tasks.

Based on the findings that social media use increases multitasking, it became important to establish whether simply engaging in social media would negatively impact performance or whether multitasking with irrelevant tasks in particular negatively impacts academic performance. Lau (2017) predicted that academically-oriented social media usage would enhance academic performance, while non-academically oriented social media usage would reduce academic performance. Hypotheses were tested using questionnaires assessing social media use for academic and non-academic purposes, social media multitasking and academic performance. Outcomes indicated that using social media for non-academic purposes and social media multitasking were both significant negative predictors of academic performance. However, using social media for academic purposes was not associated with decrements.

Based on the concept that multitasking occurs as a result of internal ("self-initiated") or external (i.e., disruptions rooted in the environment such as message notifications or a ringing phone) interruptions of an ongoing task, Adler and Benbunan-Fich (2014) investigated the effects of two different types of multitasking--mandatory (must attend to external stimuli immediately) and discretionary ("self-initiated") -- and a control condition (sequential) on performance. Participants played an easy game of Sudoku on a computer (main task - 18 minutes allotted). Although an easy game of Sudoku was selected, the level of difficulty may have been perceived differently by individuals depending on prior experience or cognitive abilities. The perceptions of difficulty were assessed, as it could be a factor affecting performance similar to the multitasking conditions. In the mandatory condition, participants were interrupted with other tasks on the screen (i.e., textual, visual, and number series tasks) and could not exit the screen to continue playing Sudoku until the allotted time was up (1.5 min or 48 seconds; allotted times were based on a pilot study). In the discretionary condition, all tasks were presented at once and participants chose when to do what. In the sequential condition, tasks were introduced one at a time; participants were not interrupted and did not multitask. The results showed that when the task is perceived to be easy, performance (in Sudoku and the other tasks) was higher in the mandatory condition than the other conditions. Performance was lower in the mandatory condition than other conditions when the task (main task – Sudoku) was perceived to be difficult. Results were explained using the Yerkes-Dodson law (Yerkes & Dodson, 1908). Specifically, they noted that when the work load was highest, additional interruptions add to the cognitive strain and hurt performance, however lower workloads are not very cognitively stimulating and additional interruptions may increase arousal and lead to better performance.

Metacognition and Multitasking in the Classroom

There is evidence that suggests that students are not accurate evaluators of their “distractive” media use, possibly due to low metacognitive skills. Kraushaar and Novak (2010) conducted a study where they observed college students use laptops during a 75-minute lesson and asked them to report their “distractive” use of media following the lesson. Analyses revealed that 25% reported iMessaging while 61% of students had actually engaged in this task. Similarly, Brasel and Gips (2011) collected observational and self-report data from students working on a laptop with a background television distraction and found that they switched their gaze from the laptop to the television eight times as much as they reported. In some cases, however, students can overestimate their online use. In a study where university students' computer usage was monitored via a software program over the course of a month, students reported spending more time on Facebook per day than they actually did (Junco, 2013). This gap between self-reported data and observational data suggests a possible lack of metacognitive awareness. If metacognitive awareness is higher, students can make strategic decisions regarding their multitasking behaviour to optimize their academic performance (Carrier et al., 2015; Kononova, Joo, & Yuan, 2016). These outcomes suggested that the present study should incorporate both self-report and observational methods when examining use of technology and metacognition.

Present Study

The two main findings of the literature that are relevant to the present study are: (1) the negative impact of media multitasking, mainly on performance and learning in educational contexts (Bowman et al., 2015; Junco, 2012c; Junco, 2015; Junco & Cotten, 2011; Junco & Cotten, 2012; Rosen et al., 2011; Wood et al., 2012), and (2) the ability to multitask without decrements in learning or inefficiencies in performance when certain conditions are met [i.e., practice and use of metacognitive strategies (e.g., planning timing); Bowman et al., 2015; Courage et al., 2015; Junco, 2012a; Junco, 2012b; Meyer & Kieras, 1967]. The present study attempts to identify the specific conditions that clearly separate these two conditions.

Hypothesis and research questions. The present study replicates and extends previous literature (e.g., Junco, 2012a; Junco, 2012c; Junco & Cotten, 2012; Wood et al., 2012). First, this study replicates previous research by examining learning gains in groups where students are required to multitask during lectures, self-select to multitask or are prohibited from media multitasking. Consistent with previous research, it is expected that media multitasking will yield lower performance than not multitasking.

Hypothesis: Those who were required to multitask (i.e., Facebook multitasking) or chose to multitask (i.e., multitasking choice) during the lecture will perform less well than those who are not required to multitask (i.e., no-technology control).

In addition to this replication, the following study explores the impact of metacognition, attitudes toward multitasking, and perceptions about the learning task as influences on learning and on multitasking behaviours. Based on the absence of related extant research, the following sets of three exploratory questions are proposed to assess metacognition, perceptions, and behaviours:

1. a) Does metacognitive awareness improve over this session? Does this vary as a function of the conditions?

   b) How do metacognitive skills impact performance?;

   c) Is metacognitive awareness (i.e., MAI) associated with metacognitive behaviours (i.e., predictions).

   d) Do metacognitive behaviours (i.e., predictions) differ as a function of condition?
2. a) Do perceptions about multitasking differ as a function of condition?;

   b) Is there a relationship between perceptions about multitasking and performance?
3. a) What do participants who have technology do during the lecture?

   b) Do those who self-select to engage in multitasking differ in their self-reported behaviour, from those who are asked to multitask?

   c) How do learning and multitasking behaviours relate to metacognition and performance?;

   d) Do attitudes toward multitasking relate to multitasking behaviour?

The qualitative analyses of the interviews provided a descriptive account of the types of multitasking present during the lecture. Additional quantitative analyses of this information showed the association between multitasking and metacognitive skills and test performance.

Method

Design

The present study contrasts three conditions (i.e., Facebook™ multitasking, multitasking choice, and no-technology control) to assess attitudes, perceptions, self-reported behaviours and observed behaviours during a standard lecture when multitasking was or was not present. The context of the study mirrored a typical classroom where students would be expected to act as they normally would (i.e., listen to a lecture, take notes, multitask using technologies, and/or zone out). Although the context was controlled as part of the study design, the elements within the classroom were created to resemble a typical lecture as closely as possible. This included using a regular classroom, having a well-known professor provide the lecture, having slides adapted from an authentic lecture used as materials, and using questions from a test-bank to assess performance. Within any given session, participants from multiple conditions were present. The presence or absence of technologies would be consistent with what is found in typical classrooms. In addition, all participants were at the same level of education. These intentional design considerations were selected to enhance ecological validity.

The Facebook™ condition involved instruction to use Facebook™ during the lecture. Students in the multitasking choice condition were instructed to attend to the lecture using technologies, notes, and other behaviours consistent with how they normally would attend to lectures. These conditions were contrasted with the control condition where students were instructed not to use technology. The present study employs self-report, observation and performance measures to assess metacognitive skills and perceived and actual multitasking abilities. During the lecture, participants in the two experimental conditions (i.e., Facebook multitasking and multitasking choice) were videotaped. Following the lecture, all participants were given a performance test. In addition, participants in the two experimental groups viewed their videos and were interviewed regarding decision-making about multitasking during lecture. This study is part of a larger study which included additional conditions and measures which are not assessed in this thesis. In summary, the present study presented the following order of events: (1) online pre-test survey completed in the class session, (2) live lecture, (3) online post-lecture survey completed in-class, (4) online post-test survey (5) interview of participants in the Facebook multitasking and multitasking choice conditions.

Participants

In total, 118 first year undergraduate students (Males = 28, Females = 90, M_{age} = 18.09, SD_{age} = 0.63) enrolled in an introductory psychology course were recruited at a mid-sized Canadian university. Ages for females (M_{age} = 18.04, SD_{age} = 0.65) and males (M_{age} = 18.25, SD_{age} = 0.52) were equivalent (t (116) = -1.52, p = 1.13). Overall, the largest self-reported ethnic affiliation was White (36.4%), followed by European (18.6%), South Asian (11%), mixed origin (8.5%), Canadian (7.6%), East/Chinese (7.6%), Hispanic/Latin (3.4%), Middle Eastern (0.8%) and Black (0.8%). An additional 5.1% of the participants either chose not to identify their ethnicity or self-identified by religion (i.e., Jewish) or another response that could not be coded (i.e., high school).

Participants were randomly assigned to one of the three conditions (i.e., Facebook multitasking, multitasking choice, and no-technology control) with approximately equal proportions of males and females in each condition. All participants received course credit for participating in this study. This study was reviewed and approved by a University Ethics Review Board and all participants were treated in accordance with APA/CPA ethical guidelines.

Materials

All materials were collected in one testing session. The materials included participant instructions, two surveys, one lecture, and one interview.

Participant instructions. A series of lecture sessions was offered. Each lecture session was held in classrooms that could accommodate between 20-40 participants. Most sessions included 10-20 participants. Participants were randomly assigned to one of three conditions: Facebook™ multitasking, multitasking choice, and no-technology control. Conditions were typically mixed within each lecture session. Each condition had a different set of instructions. Upon entry to the testing classroom, participants were presented with a consent form and an instruction card. The instruction card provided an explicit description for the condition assigned (See Appendix A for the condition instructions). Specifically, participants in the Facebook™ condition were asked to "friend the research assistant". They were told that they would receive messages and to respond to these at some point during the lecture session. Participants in the multitasking choice condition were told to participate as they normally would in a lecture. Participants in the no-technology control condition were not permitted to use any technologies during the lecture. They were provided with paper and writing implements if they wished to have these.

Pre-test survey. The measures on the pre-test survey germane to the present research include demographic information (i.e., age, gender, and ethnicity), the Metacognitive Awareness Inventory (MAI; Schraw and Dennison, 1994; see Figure 1), and a prediction score for performance on the multiple-choice test following the lecture. The MAI is a 52-item forced choice (true/false) inventory that assesses metacognitive awareness in an educational context. The measure has eight secondary subcomponents under two primary subcomponents "knowledge of cognition" and "regulation of cognition" (Schraw & Dennison, 1994). There are three subcomponents under 'knowledge of cognition', which are declarative knowledge, procedural knowledge, and conditional knowledge. The remaining five subcomponents are found under 'regulation of cognition' as planning, information management strategies, comprehension monitoring, debugging strategies, and evaluation. Reported reliability for this measure is high; Cronbach's α = .90. See Appendix B for a summary of the measures used.

Post-lecture survey. The second survey (post-lecture survey) included performance predictions for each of the six content areas covered in the lecture, an overall prediction measure for performance on the multiple-choice test, a 20-item memory performance test, and a multitasking behaviour inventory. The prediction measures asked participants to identify a percentage mark earned for each of the following six areas that were covered in the lecture; language and conditioning, extinction and spontaneous recovery, generalization and discrimination, higher-order conditioning, and variables affecting respondent conditioning. The 20-item multiple choice measure was derived from a textbook exam bank for this content area with questions randomly arranged in a static-randomized order across participants. See Appendix C for a summary of measures used.

Post-test survey. The third survey (post-test survey) contained seven questions assessing the impact of the experimental instructions on performance. Three of these questions were selected for the present study. All questions employed a five-point Likert type scale with anchors 1= strongly disagree to 5= strongly agree. The three questions assessed students' perceptions about distractions from following the instructions for the experimental conditions (i.e., “Following the experimental conditions distracted me from learning during the lecture”), about motivation resulting from experimental instruction (i.e., “Following the experimental instructions for my condition was motivating and/or interesting/fun), and about the effect of the experimental instructions on learning (i.e., “Following my instructions during the experiment did not affect my learning in any way.”). In addition, this survey contained four single-item questions assessing students’ perceptions of interest and attention to the lecture. Each item used a five-point Likert type scale (with anchors 1 = not at all and 5 = very much). The first question asked “How informative was the lecture?” The second question asked “How interesting was the lecture?” The third question asked “How attentive were you to the lecture?” The fourth question asked “How much did it matter to you to do well on the test?” Students were then asked one question about media technology as a learning tool (i.e., “Overall, how would you rate digital media technologies as a learning tool” rated on a scale ranging from 1= not at all beneficial to 5= very beneficial). The similarity of the activities in the present session to normal learning was assessed through one question asking, “How similar were the experimental activities you did today in comparison to your normal activities in a lecture?” with anchors 1= not at all similar and 5= very similar.

These questions were followed by the MAI. The two final questions on the survey assessed perceived capability of multitasking (i.e., “In your opinion, how capable are you at multitasking?”) and perceptions regarding the impact of multitasking on learning (i.e., “In your opinion, when you media multitask in the classroom, how much does it affect your learning?”). Both used a five-point Likert type scale with low scores reflecting lack of capability to multitask and low impact on learning. See Appendix D for a summary of measures used.

Lecture. The lecture was comprised of 31 PowerPoint slides on classical conditioning with six content areas; language and conditioning, extinction and spontaneous recovery, generalization and discrimination, higher-order conditioning, and variables affecting respondent conditioning. The slides were numbered in the top right corner; the slides indicating where the research assistants were required to message the participants were identified in red numbers. The slide numbers were small and placed in the corner of the screen to minimize detection. All but one lecture session was provided by the same tenured faculty member. The one exception was provided by a senior researcher. The length of the lecture was approximately 40 minutes in duration. Props used to convey content were consistent across conditions. See appendix E for a sample of the PowerPoint slides used.

Multitasking during lecture. Research assistants messaged with students in the multitasking conditions on 10 pre-specified slides. Messages were delivered to the participants as soon as the slide was shown. See Appendix F for a summary of the messaging protocols used.

Interview. One-on-one interviews were conducted. Each participant was interviewed regarding ten slides from the slide show and was asked the same questions for each slide. These ten slides coincided with the slides on which researchers prompted participants to engage in multitasking behaviours for those in the multitasking condition. However, even for students who were not in a multitasking condition, the same slides served as interview cues. At the onset of the interview, videos were rewound to the beginning of the session then forwarded to the second slide.

The protocol asked two open ended questions. The first question asked, “What is happening at this point?” The second question asked, “Can you tell me about what was going on through your mind at this point?” Participants were also prompted to elaborate on their responses with cues such as, “Can you tell me a little bit more about that?” when vague answers were provided. See Appendix G for a summary of the interview protocol used.

Recording. Cameras were mounted on tripods and were placed behind participants. In order to prevent any obstruction in participants’ line of sight, cameras were placed at the back of the room. Typically, four and at the most eight cameras were used in any given session to allow coverage of all participants. One research assistant handled one or two cameras.

Procedure

All sessions took place in a classroom context at the university. The number of research assistants attending each session varied in accordance with the demands of the conditions being tested. One research assistant assumed the lead role and directed additional research assistants and the participants.

Research assistant roles. Prior to each lecture session the lecture room was prepared to accommodate the constellation of conditions for each session. Research assistants gathered Facebook addresses from participants in the multitasking condition. Participants taking notes via paper and pencil were provided with paper and a writing utensil if necessary.

Research assistants assigned to the task of messaging the participants sent the online pre-test survey link before the lecture, the messages found on the messaging protocol during ten pre-specified slides, and the online post-lecture and post-test survey following the lecture.

Research assistants assigned to operate the cameras recorded the participants during the lecture. They stood by the camera and flashed the slide number (written on a card in marker) in front of the camera as the lecture progressed. After the post-test survey, research assistants conducted one-on-one interviews with participants in either the Facebook or natural learning conditions in a quiet area. Each participant responded to a prompt inquiring about each of the ten slides from the slide show. Participants were asked the questions on the interview protocol (see Appendix G for interview protocol) for each targeted slide.

Events for participants. Students self-selected to participate in this study by signing up through an online research participation program. Upon entry to the testing classroom, participants were presented with a consent form and condition instructions. Participants were randomly assigned to one of three conditions: multitasking choice (participate as they would in a natural classroom setting), no-technology, and Facebook multitasking. Participants were asked to review the instructions associated with their condition. All participants (including those not using technology for the rest of the session) were presented a slide with the pre-test survey Uniform Resource Locator (URL) and asked to go to the pre-test online survey. Participants completed the pre-test survey in approximately 20 minutes. Participants were then introduced to the faculty member lecturer who provided the 40-minute lecture on classical conditioning. Following the lecture, participants were provided a PowerPoint slide with the link to the post-lecture survey, which took approximately 5-10 minutes to complete. Participants were then given a five-minute study period. Participants then were provided with a slide for the post-test survey which took approximately 15 minutes to complete. Participants in the Facebook and natural learning conditions were interviewed individually by a research assistant. Due to scheduling issues, the participants in the Facebook multitasking and multitasking choice conditions were tested in mixed sessions earlier in the fall term followed by sessions for participants in the control condition.

The duration of each session lasted approximately two and a half to three and a half hours.

Plan of Analysis

This study involves both quantitative and qualitative data. The quantitative survey data were used to describe the sample of participants, and their attitudes and performance.

In addition to descriptive summaries, examination of the metacognitive and multitasking behaviours on attitudes and performance was assessed.

Performance. Performance differences across conditions were assessed using ANOVA analyses.

Metacognition. Linear regressions were conducted to assess the impact of metacognition [i.e., knowledge of cognition (declarative knowledge, procedural knowledge, and conditional knowledge), and regulation of cognition (planning, information management strategies, comprehension monitoring, debugging strategies, and evaluation)] on performance predictions and self-reported off task behaviours.

Multitasking. A sample of 20 interview responses were randomly selected, transcribed and analyzed qualitatively. Interviews were content coded using an open-coding, inductive approach where themes were developed through reading the responses (Strauss & Corbin, 1990). Themes were refined and aggregated as an iterative process as additional responses were reviewed (Sahin, 2003). Final theme labels reflect these refined categorizations. All interviews were read in their entirety.

Coding the interview data involved a series of steps. First, two coders reviewed six of the 20 interviews together, side-by-side. Potential themes were extracted until it appeared that no new additional themes or subthemes were emerging (Boyatzis, 1998). Following saturation, inter-coder reliability was calculated by having the two raters individually code five interviews (25% of total interviews). This was completed in rounds to ensure accuracy in coding and in case saturation was not fully achieved. First, the two coders scored two interviews, and attained 78%

inter-coder agreement. All disagreements were resolved by discussion and it was apparent that additional themes were needed to capture these transcriptions. Next, another set of two interviews were coded and 86.5% inter-coder reliability was achieved. Again, all disagreements were resolved by discussion. Across all four interviews, the coders reached 82.25% inter coder reliability. The coders then coded another interview on which they agreed 100%. Across all five interviews, the coders attained 86.04% inter-coder reliability. The remaining interviews were coded individually or together by the trained coders.

Results

Four aspects of the data were examined. First, performance on the quiz performance measure is presented. This is followed by a summary of outcomes for the metacognition and self-reported perception measures. Finally, a summary of outcomes from the interview are presented.

Performance on the Quiz

A total performance score was calculated by adding all items answered correctly on the quiz following the lecture. Visual inspection of mean scores indicates that, overall, performance scores were highest (67%) in the Facebook condition ($M = 13.43$, $SD = 3.15$), followed by the multitasking choice condition (62%, $M = 12.49$, $SD = 3.81$) and lowest in the no-technology control condition (58%, $M = 11.65$, $SD = 3.75$). A one-way analysis of variance was conducted to examine potential differences in performance on the quiz as a function of condition. There were no significant differences in quiz performance across conditions, F (2, 104) = 2.01, p = 0.14.

In addition to total performance scores, two additional proportion scores were calculated. One score reflected all quiz items that corresponded with lecture material/slides where a prompt to engage in multitasking was provided. The second score reflected all quiz items that did not correspond with presentation of a prompt to engage in multitasking. There were more quiz items that addressed content where a prompt was provided than when no prompt was present, thus, for each of these total scores, a proportion score was calculated where the total number of correct answers was divided by the total number of related quiz items. A 3 (condition) by 2 (multitasking prompt present versus absent) mixed model analysis of variance was conducted to compare differences in performance for each of the proportion scores as a function of condition. Condition served as the between-subjects factor and presence or absence of a prompt to multitask served as the within-subjects factor. The Pillai's Trace test supported a significant main effect for the presence or absence of prompts, F (1, 104) = 4.92, p = 0.03 (see Table 1 for a complete summary), such that mean quiz performance was higher when no prompt was present (M = 0.67, SD = 0.21) versus when prompts were present (M = 0.61, SD = 0.21). There was no main effect for condition (F (2, 104) = 2.44, p = 0.09). There was no significant interaction of presence or absence of the prompt and condition (F (2, 104) = 0.37, p = 0.69).

Metacognition

An overall metacognition score was calculated by adding all responses on the MAI measure (see Table 2 for a descriptive summary). A 2 (time: pre-lecture and post-lecture) by 3 (condition: Facebook multitasking, multitasking choice, and no-technology control) mixed model ANOVA was conducted to compare overall scores on metacognition scores over time. Time served as the within-subjects factor and condition as the between-subjects factor. Pillai's Trace did not support a significant main effect for changes in metacognitive awareness over time. However, there was a very strong trend (F (1, 92) = 3.91, p = 0.05), such that metacognitive scores were higher after the lecture (M = 39.39, SD = 8.62) than prior to the lecture (*M* = 38.31, *SD* = 6.62). There was no significant main effect for condition (F (2, 92) = 0.17, p = 0.85) and the interaction was not significant (F (2, 92) = 0.13, p = 0.88).

Further analyses of metacognition were conducted by examining the two major subscales of the Metacognitive Awareness Inventory measure: knowledge of cognition and regulation of cognition (see Table 3 for a descriptive summary). A proportional score was computed for each of the two major subscales. A mixed model analysis of variance [2 (time: pre-lecture and post-lecture) by 3 (condition: Facebook multitasking, multitasking choice, and no-technology control)] was conducted examining potential differences in these two subscales of the MAI over time and among the conditions. Time served as the within-subjects factor and condition as the between-subjects factor. Using Pillai's Trace, there were no significant main effects for knowledge of cognition (F (1, 104) = 1.58, p = 0.21; $M_{BeforeLecture}$ = 0.78, *SD* = 0.16; $M_{AfterLecture}$ = 0.80, *SD* = 0.18) or across conditions (F (2, 104) = 0.12, p = 0.88) at the multivariate level. There also was no significant interaction between knowledge of cognition and condition (F (2, 104) = 0.18, p = 0.83). However, using Pillai's Trace, there was a significant effect for regulation of cognition (F (1, 100) = 6.59, p = 0.01) at the multivariate level. Regulation of cognition scores was higher after the lecture (*M* = 0.73, *SD* = 0.18) than prior to the lecture (*M* = 0.70, *SD* = 0.14). There was no significant main effect for condition (F (2, 100) = 0.50, p = 0.61) nor was the interaction significant for the regulation of cognition scores (F (2, 100) = 0.53, p = 0.59).

Finally, metacognitive performance was examined for each of the five secondary subcomponents of the regulation of cognition component of the Metacognitive Awareness Inventory measure. The five subcomponents of regulation of cognition are planning, information management strategies, comprehension management, debugging strategies, and evaluation. To permit comparisons across the subcomponents a proportional score was calculated for each subcomponent (see Tables 4 and 5 for means). Five 2 (Time: pre-lecture and post-lecture) by 3 (condition: Facebook multitasking, multitasking choice, and no-technology control) mixed model analyses of variance were conducted to compare the scores for each of these five subcomponents. Time served as the within-subjects factor, and condition as the between subject factor in each analysis. Using Pillai's trace, two subcategories yielded significant effects for comparisons across time. Planning scores increased from pre-lecture ($M = 0.60$, $SD = 0.24$) to post-lecture ($M = 0.68$, $SD = 0.26$; $F(1, 113) = 15.13$, $p < 0.01$). Information Management Strategies scores also increased from pre-lecture ($M = 0.76$, $SD = 0.17$) to post-lecture ($M = 0.79$, $SD = 0.18$; $F(1, 108) = 5.47$, $p = 0.02$). No other main effects or interactions were statistically significant.

In summary, there was a strong trend toward increasing metacognition scores for overall assessments of metacognition. More refined analyses of the two primary subcomponents of metacognition suggest that this trend may be specific to regulation of cognition. Further investigation of this subcategory suggests that planning and information management strategies were those particularly likely to increase from before the lecture to after the lecture.

Metacognition: Predicting Performance

Analyses were conducted to examine differences among the conditions in prediction scores, followed by examination of the relationship between the MAI and prediction scores and finally, the relationship between performance and predictions was assessed.

Comparing conditions. Prior to the lecture, participants were asked to predict the overall mark they would receive out of 20 on the quiz. Overall mean scores ($M = 14.06$, $SD = 2.96$) suggest students expected to achieve approximately 70% on the quiz. One one-way analysis of variance was conducted to determine potential differences in predictions as a function of condition. There was no significant main effect (F (2, 111) = 1.91, p = 0.15).

Immediately following the lecture, students were again asked to predict how well they would do on the quiz. Overall students' mean scores (M = 13.71, SD = 3.00) reflected a slightly lower grade of 68.5% when compared to estimates before the lecture, (t (113) = 1.97, p = 0.05). A one-way analysis of variance conducted to determine potential differences among conditions after the lecture yielded no significant main effect (F (2, 115) = 0.86, p = 0.43).

MAI and prediction measures. Two linear regressions were conducted to examine the relationship between overall metacognitive awareness and predictions made before and after the lecture. Both models were significant; before, (F (1, 101) = 4.23, p = 0.04; R^2 = 0.04; β = 0.20, t (101) = 2.06, p = 0.04), and after, (F (1, 105) = 4.93, p = 0.03, R^2 = 0.05; β = .21, t (105) = 2.22, p = 0.03) the lecture, respectively. At both points in time, higher overall metacognitive awareness was associated with higher overall predictions.

Subsequent linear regression analyses examined the impact of the two primary subcomponents (i.e., regulation of cognition and knowledge of cognition) of the MAI with respect to predictions made before and after the lecture. At both time points, the overall models were significant, F (2, 100) = 3.38, p = 0.04, R^2 = 0.06 and F (2, 104) = 3.13, p = 0.05, R^2 = 0.06, respectively. Knowledge of cognition was the only significant subcomponent prior to the lecture (β = 0.25, t (100) = 2.16, p = 0.03), and was the only subcomponent to approach significance after the lecture (β = 0.21, t (104) = 0.18, p = 0.08) with higher scores in knowledge of cognition generally associated with higher predictions. Regulation of cognition was not significant in either analysis.

Predictions and performance. Two linear regression analyses were conducted to examine the relationship between predictions made before and after the lecture and outcomes on the quiz scores. Both models were significant before (F (1, 101) = 1.66, p = 0.03, R^2 = 0.04; β = 0.21, t (101) = 2.16, p = 0.03) and after (F (1, 105) = 6.15, p = 0.02, R^2 = 0.06; β = 0.24, t (105) = 2.48, p = 0.02) the lecture. Higher overall quiz scores were associated with higher performance predictions.

Two subsequent linear regression analyses were conducted to examine the relationship between predictions made before and after the lecture and proportional scores for the quiz items accompanied or not accompanied by prompts to engage in multitasking. Both models were significant, for before (F (2, 100) = 3.32, p = 0.04, R^2 = 0.06) and after (F (2, 104) = 3.76, p = .03, R^2 = 0.07) the lecture. However, predictions of performance before (β = 0.23, t (100) = 2.08, p = 0.04) and after (β = 0.21, t (104) = 1.98, p = 0.05) the lecture were associated with performance only for questions where prompts/distractions were absent. Outcomes assessing knowledge from slides where prompts were present were not significantly related to prediction scores.

Perceptions Toward Technology: A Fidelity Check

At the outset of the study, participants were asked to assess their ease with technology. This measure served as both a fidelity measure to ensure that randomization to condition was unbiased in terms of technological experience and provided a gauge of perceived skill with technologies. Mean ratings indicate that participants in all conditions rated themselves at the higher end of the scale indicating they found the technologies “easy” to “very easy” to use; Facebook multitasking (M = 4.14, SD = 0.74), multitasking choice (M = 4.37, SD = 0.65), and no-technology control (M = 4.3, SD = 0.61). A one-way analysis of variance was used to compare mean ease of use ratings across conditions. There were no significant differences among the different groups in their perceived ease with technology, F (2, 113) = 1.32, p = 0.27.

Perceptions about Personal Multitasking

Participants were asked to answer two questions regarding multitasking. The first asked participants to rate their personal capabilities and the second asked them to rate the impact of media multitasking in the classroom on learning. With respect to perceived capability, participants in all three groups rated themselves above the midpoint in the scale consistent with "somewhat capable" to "capable": Facebook multitasking (*M* = 3.14, *SD* = 0.89), multitasking choice (*M* = 3.09, *SD* = 1.00), and no-technology control (*M* = 2.93, *SD* = 0.86). Similarly, with respect to perceived impact of multitasking on learning, participants' scores reflected "somewhat" to "quite a lot" of impact on learning: Facebook multitasking (*M* = 3.44, *SD* = 0.86), multitasking choice (*M* = 3.53, *SD* = 0.94), and no-technology control (*M* = 3.64, *SD* = 0.87). A multivariate analysis was conducted to compare the three conditions on each of these two measures. Pillai's trace outcomes at the multivariate level were not significant (F (4, 222) = 0.34, p = 0.85). This outcome served as a fidelity check ensuring that groups did not differ at the outset in terms of differences in perceptions toward multitasking.

One linear regression was conducted to determine whether there was an association between perceptions and performance. Three variables, ease of technology use, perceptions of multitasking capability, and perceived multitasking impact on learning, were entered as independent variables and performance as the dependent variable. The overall model was not statistically significant (F (3, 97) = 2.39, p = 0.07, R^2 = 0.07).

Examining Performance and Metacognition

To examine the relationship between total quiz performance scores and total metacognition scores, a linear regression analysis was conducted. The regression examined pre-lecture metacognitive awareness scores and post-lecture metacognitive awareness scores. Total metacognition scores at each of the two time periods served as the independent variables and total quiz scores served as the dependent variables. The overall model was not significant (F (2, 85) = 0.32, p = 0.73, R^2 = 0.01).

A second set of two regression analyses were conducted to examine the relationship between total quiz performance scores and the proportional scores for each of the eight secondary subcomponents of metacognition. Each of the eight subcategories of metacognition at each of the two time periods served as the independent variables and total quiz scores served as the dependent variables. Neither model was significant (early assessments of metacognition: F (8, 96) = 2.02, p = 0.05, R^2 = 0.16; and later assessments of metacognition: F (8, 96) = 1.73, p = 0.10, R^2 = 0.14).

Two linear regression analyses were conducted to examine the relationship between proportional scores for quiz items related to multitasking prompts and quiz items not related to multitasking prompts with respect to overall metacognitive awareness. Neither model was significant (F (2, 88) = 1.43, p = 0.25, R^2 = 0.03; F (2, 89) = 0.20, p = 0.82, R^2 = 0.004, respectively). An additional two regression analyses were conducted to examine the relationship between proportional quiz scores (accompanied by a prompt to multitask and without a prompt to multitask) and each of the eight secondary subcomponents of metacognitive awareness. Each of the eight subcategories of metacognition at each of the two time periods served as the independent variables and proportional scores of quiz items that assessed knowledge from prompt slides or non-prompt slides served as the dependent variables. The models for the early assessments of metacognition (*F* (8, 93) = 2.45, p = 0.02, R^2 = 0.10) and the later assessments of metacognition (*F* (8, 91) = 2.98, p = 0.01, R^2 = 0.21) were significantly related to performance on quiz items assessing knowledge on slides where participants were prompted. Only one subcategory of regulation of cognition involving debugging strategies was significant in the early assessments (t (93) = 2.53, p = 0.01) such that higher debugging strategies was related to higher scores on quiz items assessing knowledge on prompt slides β = 0.26. Three subcategories of the regulation of cognition involving comprehension monitoring (t (91) = -3.06, p = 0.003), debugging strategies (t (91) = 2.01, p = 0.05), and evaluation (t (91) = 2.00, p = 0.05) were significant in the later assessments, such that higher comprehension monitoring was related to lower scores on quiz items assessing knowledge on prompt slides β = -0.46, higher debugging strategies was related to higher scores on quiz items assessing knowledge on prompt slides β = 0.24, and higher evaluation was related to higher scores on quiz items assessing knowledge on prompt slides β = 0.28. All analyses examining slides for which participants were not prompted to multitask were not significant.

Examining Multitasking and Metacognition

To examine the relationship of metacognitive awareness and multitasking, two linear regression analyses were conducted. Each of the eight subcategories of metacognition at each of the two time periods served as the independent variables and rated capability of multitasking as the dependent variable. Neither model was significant (early assessments of metacognition: *F* (8, 102) = 0.30, p = 0.96, R^2 = 0.03; and later assessments of metacognition: *F* (8, 100) = 1.09, p = 0.38, R^2 = 0.09).

In addition, the relationship between perceived impact of multitasking on learning and metacognition was assessed through two linear regressions. Each of the eight subcategories of metacognition at each of the two time periods served as the independent variables and rated impact of multitasking on learning as the dependent variable. Only the model for the early assessments of metacognition (F (8, 104) = 2.75, p = 0.01, R^2 = 0.19) was significant. Only one subcategory of regulation of cognition involving comprehension monitoring was significant (t (104) = 3.89, p < 0.001), such that higher comprehension monitoring awareness was related to perceived greater impact of multitasking on learning β = 0.46. The model for later assessment of metacognition (F (8, 102) = 1.01, p = 0.43, R^2 = 0.08) was not significant.

Examining Interview Data for Reports of Multitasking and Learning

A subsample of 10 randomly selected interviews from each of the Facebook multitasking and multitasking choice conditions were transcribed. The information provided by students was thematically coded. Two broad thematic categories were identified. The first was related to multitasking issues and the second to learning issues. Initially, 33 unique themes were extracted from the interviews; 19 of those themes were related to multitasking and 15 were related to learning (see Appendices H and I for a complete summary of themes and Tables 6 and 7 for a complete summary descriptive data). Two additional themes, “I don’t know” and “irrelevant” captured interview responses where the participants were simply unable to describe what was happening when they were viewing the video (see Appendix J for a complete summary of themes and Table 8 for a complete summary of descriptive data). The “I don’t know” code was used only when it was the participants’ only response to a question. The irrelevant theme was used to identify comments made by participants that were not related to multitasking or learning or the videos being viewed.

Within the 19 themes related to multitasking and the 15 themes related to learning, there were several that shared some general ideas even when specific instances were not identical.

These related themes were subsequently aggregated, resulting in a total of seven themes for each of the multitasking and learning themes (see Appendix K and L for a complete summary of aggregated themes). Only the results of the aggregated themes are presented in subsequent analyses (see Tables 9 and 10 for the descriptive summary of each of the seven multitasking and learning themes, respectively).

Multitasking themes. The frequency of engaging in each of the seven multitasking related behaviours was calculated as a function of condition and as an overall score. With respect to the overall frequency of these multitasking behaviours, the most prominent theme occurring 120 times involved students describing themselves engaged with multiple activities. This "engaged in many things" (from here on referred to as "many things") theme included splitting the screen to view more than one window at a time, half-listening to the lecture while doing something else, pausing from attending to the lecture and/or note-taking to do something else, dual-tasking, multitasking and only focusing on tasks other than the lecture. The "many things" theme was also the most prevalent theme in each of the two conditions, 34 occurrences in the Facebook condition and 86 occurrences in the multitasking choice condition. The second most frequently identified theme involved responding to messages sent either by the research assistants or from another source, with 46 occurrences overall, most of these were reported by students in the Facebook multitasking condition. Those in the Facebook multitasking condition (41 occurrences, $M = 4.10$, $SD = 2.77$) reported being distracted by messages, waiting for messages, catching up with messages, answering messages or finding messages less distracting over time. Few occurrences of these kinds of thoughts, only five in total, were reported by those in the multitasking choice condition. Thus, students in both conditions were actively engaged in multitasking in this study.

Remaining multitasking sub-themes, though relevant, occurred relatively infrequently. Specifically, deciding not to make Facebook responding a priority, making the choice to understand and attend to the lecture before multitasking, and/or planning or thinking about multitasking occurred in both conditions, although most frequently in the Facebook multitasking condition than the multitasking choice condition. Participants in the Facebook multitasking condition described the ease of preparing and sending messages as a function of familiarity with lecture content (8 occurrences, $M = 0.80$, $SD = 1.41$). This theme did not appear in the multitasking choice condition. These themes indicate that students were actively making strategic decisions regarding multitasking in the Facebook multitasking condition.

Interestingly, students in both conditions identified some level of conflict between their perceived need to multitask (e.g., respond to messages) and the need to attend to the lecture and/or take notes. This was a more prevalent concern in the Facebook multitasking condition (12 occurrences) than in the multitasking choice condition (three occurrences). Overall, those in the Facebook multitasking condition reported multitasking more than the multitasking choice condition. One t-test was conducted to assess differences between the Facebook multitasking and the multitasking choice conditions with respect to reported engagement in many things. There was a significant difference between the conditions in doing “many things” (t (18) = -2.26, p = 0.04). Participants in the multitasking choice condition ($M = 8.60$, $SD = 6.74$) engaged in multiple multitasking behaviours more frequently than those in the Facebook multitasking condition ($M = 3.40$, $SD = 2.72$).

For many of the themes, frequency rates were quite low. Given that this was an exploratory study, three additional t-tests were conducted to assess potential differences between the two multitasking groups with respect to the number of prompts/messages that were (a) a concern, (b) concerns about putting their lesson first, or (c) invasive thoughts about multitasking. There was a significant difference between the conditions for 'prompt/message related' behaviour (t (18) = 4.04, p = 0.001) with participants in the Facebook multitasking condition (M = 4.10, SD = 2.77) were engaged with prompts or messages more than those in the multitasking choice condition (M = 0.50, SD = 0.53). There were no significant differences between the groups for concerns about putting the lessons in first and invasive thoughts about multitasking.

Learning themes. The frequency of engaging in each of the seven learning-related behaviours was calculated as a function of condition and as an overall score. Engaging in note taking and attending to the lecture were the two most frequently cited sub-themes pertaining to the learning theme for both conditions (130 and 121 total occurrences, respectively, see Table 10). Interestingly, the third most frequent sub-theme involved monitoring (84 occurrences), where students were actively assessing what they understood in the lecture content. Monitoring involved tracking one's own understanding of lecture content, understanding the impact of one's own behaviour on attending and engaging with the lecture, and being aware of missed content. The theme, involved with content (i.e., trying to make notes make sense to learner, tying to prior knowledge, reflecting on the content) occurred a total of 60 times, with 28 occurrences in the Facebook multitasking condition and 32 occurrences in the multitasking choice condition. In addition, students also indicated planning and engaging in strategies (five occurrences), which could be defined as thinking about taking notes, attending to the ongoing lecture, or engaging with the lecture content and using strategies like imagery to do that. These themes are consistent with constructs of metacognition. With respect to selecting important lecture content where there were 11 occurrences in total and more specifically nine occurrences in the Facebook multitasking condition and two occurrences in the multitasking choice condition. This subtheme reflected identifying critical information to stay focused on the important and themes of the lecture.

In addition to these subthemes students also identified instances where they were not following the content of the lecture (45 occurrences). This sub-theme captured challenges related to the lecture context. For some students this inability to engage fully was a function of boredom, losing interest, losing focus, getting tired, choosing not to pay attention, or becoming overwhelmed by the fast pace of the lecture. Participants in the multitasking choice condition (31 occurrences) reported being unable to fully engage more often than did those in the Facebook multitasking condition (14 occurrences).

A series of five t-tests were conducted to examine potential differences between the two groups for the following five themes (note-taking, attending to the lecture, monitoring, involved with content, not following content). Remaining categories could not be analyzed due to infrequent occurrence. There were no significant differences between the two conditions for all of these five learning related themes.

Metacognitive behaviour and performance. Correlations were conducted for three frequently-occurring learning-related behaviours and performance on the quiz: attending to lecture, monitoring, and note-taking. Each of these behaviours reflects content assessed through the MAI, and each had sufficient numbers of occurrences to permit exploratory analysis. With respect to the overall total quiz scores, attending to the lecture and monitoring were not correlated ($r = 0.13$, $n = 18$, $p = 0.60$; $r = -0.05$, $n = 18$, $p = 0.84$, respectively), however, note-taking was positively correlated with overall performance ($r = 0.65$, $n = 18$, $p = 0.003$). Examination of correlations between proportional scores for the quiz questions associated with prompts yielded no significant correlations for any of the three behaviours: attending to the lecture (*r* = 0.20, *n* = 19, *p* = 0.42), monitoring (*r* = -0.13, *n* = 19, *p* = 0.60) or note-taking (*r* = 0.25, *n* = 19, *p* = 0.30). Correlations between performance on quiz items not associated with researchers providing prompts or messages yielded no correlation for attending to the lecture (*r* = -0.23, *n* = 19, *p* = 0.34) or monitoring (*r* = -0.16, *n* = 19, *p* = 0.53), however, again, there was a significant correlation for note-taking (*r* = 0.47, *n* = 19, *p* = 0.04).

Multitasking behaviour and metacognition. The relationship between the theme involving monitoring and metacognition was assessed through two correlations to assess relationships at time one and time two. Monitoring was not correlated with pre (*r* = -0.41, *n* = 19, *p* = 0.09) and post (*r* = -0.43, *n* = 18, *p* = 0.07) measures of overall metacognition scores. In addition, a series of four correlations were conducted to assess the relationship between monitoring and each of the two primary subcomponents of the MAI for each of the two different time points. None of the correlations were significant. Finally, two correlations were conducted to examine the relationship between the secondary comprehension monitoring subcomponent of regulation of cognition and self-reported monitoring during the lecture. There was a significant relationship both before and after the lecture. (*r* = -0.52, *n* = 20, *p* = 0.02; *r* = -0.63, *n* = 19, *p* = 0.004, respectively). Higher scores in reported monitoring were associated with higher monitoring scores on the MAI.

Multitasking behaviour and performance. To assess the relationship between multitasking behaviours and performance, correlations were conducted to examine total and proportional performance scores for each of the two reported multitasking behaviours (i.e., “many things” and “prompts”). There was no correlation between total performance scores and reported multitasking (“many things”: *r* = -0.25, *n* = 18, *p* = 0.32; “prompts”: *r* = 0.10, *n* = 18, *p* = 0.69).

Reported multitasking was not correlated (“many things”: $r = -0.01$, $n = 19$, $p = 0.98$; “prompts”: $r = 0.16$, $n = 19$, $p = 0.52$) with proportional scores of quiz questions not associated with prompts. Proportional scores of quiz questions associated with prompts was negatively correlated with “many things” ($r = -0.51$, $n = 19$, $p = 0.03$), but not correlated with “prompts” ($r = 0.09$, $n = 19$, $p = 0.71$).

Two additional correlations looked at the relationship between total and proportional performance scores and reported multitasking as a function of condition. There were no significant correlations.

Perceptions of multitasking and multitasking behaviour. Pearson correlations were conducted to determine potential relationships between multitasking behaviour that required responding and self-selected multitasking with each of the three perceptions ratings (perceived ease with technology, perceived capability of multitasking, and perceived impact of multitasking). Participants’ multitasking behaviours were not correlated with any of the perception measures.

Discussion

The goals of the present study were to document student behaviours regarding multitasking and learning during lecture when interacting with technologies was required, and when choice to interact could be made. Performance in these contexts was compared to learning when no technologies were present. In addition, the study examined the impact of metacognition on student learning and the role of students’ behaviours when technologies are present. The study also provided an opportunity to replicate previous literature regarding students’ perceptions of multitasking capability (e.g., Junco, 2012a; Junco, 2012c; Junco & Cotten, 2012; Wood et al., 2012). The direct observation of student activities during learning, especially with respect to technologies, provided a more complex and comprehensive understanding of how students use technologies in the context of the many other activities that students engage in while attempting to learn from lectures. As expected, metacognitive awareness did impact some outcomes but did not uniformly impact learning or behaviours in this lecture context. The present study yielded mixed outcomes with respect to previous research. Consideration of these outcomes is addressed as a function of proposed hypotheses below.

Hypothesis: Those who were required to multitask (i.e., Facebook multitasking) or chose to multitask (i.e., multitasking choice) during the lecture would perform less well than those who are not required to multitask (i.e., no-technology control).

Contradictory to the first hypothesis, analyses of overall performance differences did not detect any differences between those who did multitask and those who did not multitask. This finding does not align with previous findings (Junco, 2012c; Junco, 2015, Junco & Cotten, 2011; Junco & Cotton 2012; Rosen et al., 2011; Wood et al., 2012) where learning decrements were observed following use of technologies while learning. It is possible that the nature and requirements of the lecture involved in the present study were less demanding than in previous studies. For example, Wood and colleagues (2012) examined longer lectures in a required upper year statistics and methods course, which may have required greater sustained attention than the lecture used in the present study. However, it could also be argued that traditional learning models, the topic presented in the lecture, would be challenging material for students at the introductory level. Consideration of level of study might be an important variable to examine in future research.

More generally, it is possible that the task demands in the current lecture were simple enough for parallel processing to occur without a detectable level of interference (Cardoso-Leite, 2015). The act of messaging may be so well practiced that it can be performed easily and quickly. It is also possible that one task on its own was not stimulating or challenging enough to exceed students' pool of attentional resources. There may have been enough attentional resources (Pashler, 1994) to perform a second task.

Additionally, the act of listening to a lecture and reading a message may draw upon, and hence tax, different cognitive resources (i.e., auditory and visual processes; Cardoso-Leite, 2015; Meyer & Kiernas, 1997b). Furthermore, participants were able to respond to messages whenever they wished; they could have been strategic with the timing of tasks to not constrain "the temporal relations or serial order among responses" (Courage et al., 2015, pg. 9; Meyer & Kiernas, 1997b). Indeed, the results from the qualitative interview data indicate strategic decision-making regarding when to respond to messages. There were instances where participants actively decided not to make Facebook responding a priority and instead made the choice to understand and attend to the lecture before engaging in multitasking. Task appropriate behaviours such as note-taking, attending to the lecture, monitoring, and strategy use were also commonly reported behaviours during instances when prompted messages were being sent, thus learners were clearly choosing to engage in the learning task despite having the opportunity to multitask. Also, it is important to note that in this study the messages that were being sent to the participants were task relevant, that is, they were relevant to the information they were learning in that moment. Using social media for academic purposes has not been associated with poor academic performance (Lau, 2017). As a result, the nature of the messages may have prevented any costs that would have occurred otherwise.

A more detailed analysis was conducted to determine whether there were differences in participants' performance on quiz questions assessing knowledge of slide content when students in the Facebook condition were not interrupted versus when they were interrupted by messages from the research assistants. In general, scores were higher for questions testing knowledge of slide content when participants were not interrupted by messages from the research assistants. Although this main effect confirms previous findings of the distractive value of incoming messages (Junco, 2012c; Junco, 2015; Junco & Cotten, 2011; Junco & Cotten, 2012; Rosen et al., 2011; Wood et al., 2012), this global outcome was not expected in conditions where messages were systematically sent or in conditions where no technology was present.

Only those in the Facebook multitasking condition were messaged by research assistants for each of the predetermined slides, therefore, it was expected that participants in the Facebook multitasking condition would demonstrate greater negative impact from these interruptions. The uniform negative impact on performance may be the result of students in the other conditions being distracted by the off-task activities of their peers (Brasel & Gips, 2011). Alternatively, it could be the case that the urge to engage in multitasking was so strong that all participants, especially those in the conditions with technologies, felt the need to engage in multitasking (e.g., Carrier et al., 2015; Nielsen, 2010; Wood & Zivcakova, 2015). The qualitative interview data indicate that within the two technology-equipped conditions, media-based multitasking, although more common in the Facebook multitasking condition, was a prominent theme in both conditions. Although participants in the no-technology use control condition were instructed not to use technologies, it is a possible that they ignored instructions and engaged in multitasking. Given that this group was not targeted for the video recordings, nor were they interviewed, it is hard to determine what, if any, media based activities they may have engaged in or were distracted by during the session. In future research, it would be an important question to address just how keenly this group conformed to instructions by recording and interviewing them.

One additional possibility to consider is that the multiple choice questions varied in difficulty for those specific to prompted messages versus those regarding material when prompts and messages were absent. This interpretation of outcomes is less likely. The current presentation content and quiz items were based on well-established lecture materials and testing instruments. The questions were rated equally with respect to design and demands consistent with Bloom's taxonomy (Bloom, Englehart, Furst, Hill, & Krathwohl, 1956) and had been used with a similar target population without noted differences among the questions.

Exploratory Question 1. a) Does metacognitive awareness improve over this session? Does this vary as a function of the conditions?

Interestingly, metacognitive awareness scores demonstrated a marginally significant increase over time. Given the short time between the first assessment and second, this increase might be unexpected. It is possible that key elements of the design of the study may have contributed to increases. Specifically, asking students to complete the MAI prior to the lecture may have primed students to assess their learning strategies and learning as they progressed through the lecture. In addition, students were explicitly required to engage in metacognitive behaviours. Students predicted their performance prior to being administered the second MAI. Given the potential priming and active engagement in metacognitive behaviours, it is perhaps not surprising that their scores demonstrated a strong trend toward increases over time (e.g. Schraw, 1998). The trend found here suggests that repeated opportunities for students to clearly assess the impact of media-multitasking on learning might facilitate learning and understanding of media-multitasking behaviours.

The trend toward significant differences, rather than achieving statistically significant differences, may be the result of insufficient time for the multiple aspects of metacognition to change. Subsequent analyses showed that the regulation of cognition primary subcomponent of metacognitive awareness, in particular increased over time. More specifically, planning and information management strategies increased from before the lecture to after the lecture. It is possible that participants were better able to calibrate the demands of the task and allocate appropriate resources after experiencing the lecture and assessing how they performed in attending, note-taking, and recalling information. Participants in one condition knew ahead of time that they would receive messages at some points in the lecture while those in the choice condition knew that they could initiate or respond to media-based interactions as they saw fit. Thus, consistent with the expectations set out by Mayer & Kieras (1997b), two groups of students had reason and an opportunity to plan ahead and strategically allocate resources and execute tasks in appropriate temporal and serial relation to the critical information in the lecture. They could have used this information and their account of their usual media multitasking and/or lecture behaviour to develop and execute an appropriate plan for themselves and their learning. Students in the no technology condition were able to plan attentional resources consistent with how they traditionally approach lectures, or, alternatively, the absence of technologies may have required them to actively consider allocation of attentional and strategic resources in the absence of technologies that they would otherwise have available during a typical lecture. In all cases, students had an opportunity to engage metacognitive skills to learn, thus enhancing metacognitive awareness.

Information management strategies focus on the use of the repertoire of strategies available to each student to efficiently and effectively process information. The lecture provided the students with the opportunity to use and develop information management strategies. For example, having to handle incoming messages and process the live lecture stream required participants to carefully, selectively and critically choose when to attend and/or when to take notes. For those in the Facebook condition, the questions that were asked by the research assistants were specific to the lecture content being presented at that moment. These relevant prompts/messages could potentially have encouraged participants to organize, summarize and elaborate on the information in order to quickly and successfully form an answer to the research assistant. There were no differences among conditions over time, however; with respect to information management strategies. The experience of the lecture, therefore, rather than the task-specific prompts provided to the one condition, appears to be the most salient contributor to improvement in information management strategies.

Other aspects of metacognitive awareness did not show improvement over time. It could be that the duration or design of the lecture did not tap into these aspects as saliently as the lecture format employed in the present study. Perhaps different instructional opportunities (e.g., seminars, discussions, experimentation, and reflections) might have afforded greater awareness and development of other metacognitive sub-skills. Alternatively, these skills may need to be explicitly cued or instructed in order to facilitate development (e.g., Schneider, 2010).

Exploratory Questions 1. b) How would metacognitive awareness impact performance? c) Would metacognitive awareness (i.e., MAI) be associated with metacognitive behaviours (i.e., predictions)?

There was a positive correlation between some aspects of cognitive awareness and prediction scores. More specifically, higher knowledge of cognition scores significantly predicted higher performance predictions before the lecture and there was a trend toward significance with predictions made after the lecture. Both predictions made before and after the lecture were related to quiz performance; however, only for items where no prompt or message was provided by the research assistants. It is possible that students based their predictions on material that most closely matched uninterrupted learning settings, thus resulting in higher predictions of success.

Several subcategories of metacognition, however, were associated with quiz scores assessing knowledge from slides during which messages were sent to the participant. Specifically, higher debugging strategy scores both before and after the lecture and higher evaluation scores after the lecture reflected higher scores on the slides associated with messages sent to the students. Higher comprehension monitoring scores after the lecture predicted lower scores on the message slides. In these situations, it appears that execution of these strategies may have signalled challenging content or challenging tasks to the learner and, hence, resulted in less positive learning outcomes.

Overall, the relationship between metacognitive awareness and performance was complex, with some aspects of cognitive awareness being more relevant in this learning task than others. It would be interesting to explore these relationships with other learning tasks, such as seminars or labs, to see if similar aspects of metacognition prove equally important across contexts.

Exploratory Question 1. d) Would metacognitive behaviours (i.e., predictions) differ as a function of condition?

Improved metacognitive awareness was also evident in the reduction of prediction scores over time. There was a trend toward decreasing predictions of quiz performance after listening to the lecture than before listening to the lecture. Perhaps having experienced the lecture, participants adjusted their predictions of performance to reflect the challenging aspects of the information they heard about in the lecture. At the outset of the study, participants may have assumed that they would easily learn and comprehend the information presented in the lecture, and answer questions about it. After experience, these skilled learners likely used metacognitive awareness to assess their potential performance realistically, and, hence reduced their predicted scores.

One concern that needs to be considered when dealing with prediction measures is that a significant body of literature indicates that learners can both underestimate (Kraushaar & Novak, 2010; Brasel & Gips, 2011) or overestimate (Junco, 2013) their performance of studying, working, attending to a lesson and multitasking. In fact, reducing this problem requires substantial opportunities to hone metacognitive awareness and skills in the targeted setting (Carrier et al., 2015; Kononova, Joo, & Yuan, 2016). The present findings suggest that the lecture context employed in the present study provided some support for students to refine their prediction assessments.

Exploratory Questions 2. a) Would perceptions about multitasking differ as a function of condition? b) Would there be a relationship between perceptions about multitasking and performance?

On average, participants indicated that they found technology ‘easy’ to ‘very easy’ to use and they reported that they are ‘somewhat capable’ to ‘capable’ of using technology. Participants said that their learning is impacted by multitasking ‘somewhat’ to ‘quite a lot’. Responses to these questions are consistent with similar questions in the literature and support the similarity of the present sample with other groups of students tested within the literature (e.g., Wood et al., 2012).

Overall, there were no differences among the three conditions with respect to their beliefs about their ability to use technologies or the impact that multitasking with technology has on learning. This lack of difference serves as a fidelity check for the randomization of participants to condition.

Participants' views of how easy it is to use technologies and how capable they are of using technologies would suggest that they have a fair amount of knowledge about the use of technologies and a fair amount of practice with technologies. It could be suggested that this outcome may partly explain why there was no difference in quiz performance between multitaskers and non-multitaskers. All participants reported strong multitasking abilities, thus they would be expected to perform well despite the interference from media multitasking. Performance measures, however, do not support this assertion. Specifically, performance was lower for items related to interference from prompts.

Although participants indicated that they found technology easy to use and they believe themselves to be very capable of using technologies, they also endorsed the negative impact that multitasking can have on learning. That students can hold these two beliefs simultaneously is particularly important in terms of metacognitive development. Students who hold both of these beliefs may be less able to make accurate predictions about their learning when their learning context allows them to engage in multitasking with technology. They may perceive their fluency with technology lessens the negative impact on learning. This possibility suggests that today's media-rich learning environments may require specific instructional opportunities to assist students in understanding the disconnect between perceived media fluency and learning outcomes when media is used ineffectively during learning tasks (e.g., Junco & Cotton, 2011).

Exploratory Question 3. a) What would participants who have technology do during the lecture?

Throughout the lecture, both participants who were required to have technology to media multitask and participants who were free to have or not have technology to make media multitasking choices engaged in multitasking and learning-related behaviours. However, those who were required to media multitask reported multitasking more than those who were free to choose to multitask or to not multitask. Those who were free to choose to multitask or not reported engaging in learning-related behaviours more than those who were required to multitask. Interestingly, whether required to use technology or not, students frequently engaged in media multitasking. This is not surprising, considering the prevalence of technology use in today's society across social, academic and business contexts (e.g., Carrier, et al., 2015; Nielsen, 2010), and increasing suggestions that engaging in media multitasking may reflect an increasing dependence or addiction to technology (e.g., Wood & Zivcakova, 2015). Results from the present study reinforce that students typically maintain divided attention (e.g., Courage et al., 2015; Pashler, 1994) between learning the information presented and multitasking with irrelevant media activities during a real time lecture. Interestingly, when students engaged in media-based multitasking, only a few students reported behaviours that would be consistent with the dual-tasking understanding of multitasking (e.g., Cardoso-Leite et al., 2015; Courage et al., 2015; Pashler, 1994) while many of the multitasking behaviours were consistent with rapid switching between tasks (e.g., Courage et al., 2015; Pashler, 1994).

Exploratory Question 3. b) Would those who self-select to engage in multitasking differ in their self-reported behaviour from those who are asked to multitask?

The multitasking choice group was instructed to attend to the lecture as they would a 'normal' lecture. They were not asked to multitask or prompted to multitask, but they were also free to do that. The Facebook multitasking group received messages from the research assistants at specific time points in the lecture and they were instructed to respond to these prompts whenever they wanted. Participants in the Facebook multitasking condition reported catching up with prompts, finding prompts or technology distracting, waiting for prompts, and answering prompts (these items were grouped under the more general category "many things") more than those in the multitasking choice group. However, those in the multitasking choice condition reported viewing more than one window on the screen, half-listening, pausing from the lecture to do other things, dual tasking, engaging in other types of multitasking, and only focusing on task(s) not related to the lecture (these items were grouped under the more global category "prompts") more than those in the Facebook multitasking group. Thus, although the conditions differed in the way they multitasked, they did not significantly differ in the amount of multitasking they engaged in as indicated by the aggregated score of these two types of multitasking. Clearly, these outcomes support previous literature noting that students do engage in media multitasking during lectures (e.g., Carrier et al., 2015; Courage et al., 2015).

What is interesting in the present study is the impact of the different instructions on students' focus regarding multitasking. Those in the Facebook condition were preoccupied with concerns about how best to address the prompts and messages sent to them by the research assistant. Their attention to the messages is consistent with the literature indicating a compulsion to attend to messages (Wood & Zivcakova, 2015). Students who had the choice to engage in media multitasking, on the other hand, were 'busy' in a multitude of ways. These interesting differences are particularly compelling for understanding how different uses of technologies in classrooms might shift how students manage technology, time and attention. For example, an active learning classroom that requires students to respond to messages from other class members may elicit behaviours consistent with those in the Facebook condition of the current study, whereas another classroom that does not have such demands may permit more diverse forms of media multitasking consistent with those in the multitasking choice condition. It would be important in future research to examine how the perceived demands associated with different instructional demands regarding media use impact how students assign their time and cognitive resources.

Exploratory Question 3. c) How would learning and multitasking behaviours relate to metacognition and performance?

Total and proportional quiz scores were not associated with the frequency of either of the two aggregated multitasking themes (i.e., “many things” and “prompts/messages”) with one exception. The scores for multiple choice items that coincided with times in the lecture when researchers sent prompts or messages were negatively correlated with the “many things” theme. In other words, higher multitasking scores were associated with lower performance scores for items that tested material when prompts of messages were sent out by research assistants. This most likely reflects a distraction to students when the research assistants sent the prompts/messages even if students did not respond right away. This distraction may have resulted in missed lecture content that was later assessed in the quiz.

Self-reported monitoring, a theme consistent with the constructs of metacognition (e.g., Schraw, 1998), was not correlated with the early and later assessments of metacognition, regulation of cognition, and comprehension monitoring. However, it was negatively associated with the early and later assessments of knowledge of cognition. Lower scores for knowledge of cognition were associated with higher reported frequency of monitoring. Although monitoring is more closely related to regulation of cognition and its subcomponents, particularly comprehension monitoring, a correlation between reported monitoring and regulation of cognition and/or comprehension monitoring would have been expected. However, the interdependence between the subcomponents of metacognition (Schraw, 1998) may have required that participants reach a certain level of knowledge in cognition (which did not increase significantly over time in the present study) before developing the skill to monitor well. Similarly, participants who lack knowledge of cognition may perceive their own behaviours as monitoring when it may not be. This may be why self-reported monitoring was not correlated with metacognition, regulation of cognition, and comprehension monitoring. Participants may believe they are engaging in monitoring when they are not, which could represent a gap between perceptions and reality (Brasel & Gips, 2011; Kraushaar & Novak, 2010) due to low metacognitive awareness.

Attending to the lecture, monitoring, and note-taking, which are themes consistent with the constructs of metacognition, were correlated with performance scores. However, only note-taking was significantly associated with performance. Specifically, note-taking was positively correlated with total quiz scores and the proportion scores for quiz items that were not associated with times when the research assistants sent prompts. This relationship would be expected given the vast literature on note-taking that indicates the value of note-taking for learning (e.g., Carrier et al., 2015). This outcome also suggests that students may not be taking notes or taking poor notes when distracted. This outcome has important implications for learning as students who are distracted with technology may be less able to engage with the notes later because they did not form strong semantic connections (Anderson & Pearson, 1984) and build domain knowledge (Bédard & Chi, 1992; Symons & Pressley, 1993; Willoughby, Anderson, Wood, Mueller, & Ross, 2009) during the lecture.

Exploratory Question 3. d) Would attitudes toward multitasking relate to multitasking behaviour?

Attitudes toward multitasking (i.e., perceived ease with technology, perceived capability of multitasking, and perceived impact of multitasking) were not associated with multitasking behaviours. People's claims about their technology use and multitasking abilities were not predictors of the multitasking behaviours they performed. These results may reflect a lack of metacognitive awareness when making multitasking related judgments.

Limitations

There are two main limitations in the present study. First, the present study included a control condition where no technology was expected to be used. Use of technology could not be wholly controlled given that the study was conducted using larger groups of students in a classroom context. In addition, considerable focus was placed on the two media groups, including video-taping. There were no video tapes or interviews of the control condition participants. It would be useful in future research to video-tape and interview participants in the control condition parallel to the way participants in the other conditions were tested to allow for more robust conclusions regarding what was occurring during the session. Future studies could expand recording to include those in no technology control groups to ensure study fidelity.

Additionally, the participants for the no-technology control condition were recruited closer to the end of the semester, and were tested together while the participants for the other conditions were recruited in the middle of the semester and were tested in mixed groupings. This may have influenced outcomes as students leaving participation until later in the term may be different than those registering early. For example, students might have differed in terms of planning, program scheduling, workload associated with programs, or commitment to work in their psychology program.

Finally, although interview questions were open-ended and scripted, and permitted a more extensive understanding of what students were doing during the learning session, a more immediate data collection system, such as talk aloud protocols might have yielded more complete findings. Some students indicated that they did not remember what they were doing even while watching their video. This may reflect poor monitoring but also might reflect memory loss over time.

Future Directions

The present study examined the relationships between metacognition, multitasking, predictions, and performance in a single, relatively brief learning context. Future research could investigate these variables over longer periods of time. For example, examining participants every week for 12 weeks during a 40-minute lecture would mirror a typical university level course more closely. This type of design would provide more substantial opportunities for metacognitive skills to develop. Future research could also examine other forms of "interventions". For example, lecture, seminar or lab contexts would be important instructional formats to examine as each has different task demands thus, the effects of multitasking may change under each of these conditions.

Closing Comments

The present study documented student behaviours regarding multitasking and learning during lecture when interacting with technologies was required and when choice to interact could be made. The outcomes were clear; students engage in a diversity of activities during lectures whether they are asked to use technology or not. The direct observation of student activities during learning, especially with respect to technologies, provided a more complex and comprehensive understanding of how students use technologies in the context of the many other activities that students engage in while attempting to learn from lectures. Metacognitive awareness impacted some aspects of this ‘busy’ learning environment in the present study. Knowing more about how to enhance or encourage metacognitive strategies when technology is used would be a critical future direction.

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Tables and Figures

Table 1

Means and Standard Deviations for Proportional Performance Scores When Prompts to Multitask were Present or Absent Across Conditions

	Multitasking Prompt Present M (SD)	No Multitasking Prompt M (SD)
Facebook Multitasking	0.65 (0.19)	0.72 (0.19)
Multitasking Choice	0.61 (0.22)	0.66 (0.21)
No-Technology Control	0.57 (0.21)	0.60 (0.21)
Total (across all conditions)	0.61 (0.21)	0.67 (0.21)

Table 2

Means and Standard Deviations for Overall Metacognition Awareness Inventory Scores Before and After the Lecture Across Conditions

	MAI Scores Before Lecture M (SD)	MAI Scores After Lecture M (SD)
Facebook Multitasking	38.29 (5.90)	39.71 (6.92)
Multitasking Choice	37.91 (7.25)	38.71 (9.02)
No-Technology Control	38.88 (6.88)	39.88 (10.33)
Total	38.31 (6.62)	39.39 (8.62)

Table 3

Descriptive Summary of the Regulation of Cognition and Knowledge of Cognition Proportional Metacognition Scores – Before and After the Lecture for each condition

	Regulation of Cognition		Knowledge of Cognition	
	Before Lecture M (SD)	After Lecture M (SD)	Before Lecture M (SD)	After Lecture M (SD)
Facebook Multitasking	0.70 (0.13)	0.73 (0.15)	0.79 (0.14)	0.81 (0.15)
Multitasking Choice	0.70 (0.16)	0.72 (0.20)	0.77 (0.17)	0.79 (0.18)
No-Technology Control	0.72 (0.13)	0.77 (0.19)	0.79 (0.17)	0.80 (0.23)
Total	0.70 (0.14)	0.73 (0.18)	0.78 (0.16)	0.80 (0.18)

Table 4

Proportional Means and Standard Deviations for the Planning and Information Management Strategies Sub-Scores of the Metacognitive Awareness Inventory Before and After the Lecture Across Conditions

	Planning		Information Management Strategies	
	Before Lecture M (SD)	After Lecture M (SD)	Before Lecture M (SD)	After Lecture M (SD)
Facebook Multitasking	0.58 (0.23)	0.67 (0.22)	0.76 (0.14)	0.80 (0.18)
Multitasking Choice	0.64 (0.25)	0.65 (0.28)	0.74 (0.20)	0.78 (0.19)
No-Technology Control	0.57 (0.24)	0.75 (0.26)	0.78 (0.15)	0.81 (0.18)
Total	0.61 (0.24)	0.68 (0.26)	0.76 (0.17)	0.80 (0.18)

Table 5

Proportional Means and Standard Deviations for the Comprehension management, Debugging Strategies and Evaluation Sub-Scores of the Metacognitive Awareness Inventory Before and After the Lecture Across Conditions

	Comprehension Management		Debugging Strategies		Evaluation	
	Before Lecture M (SD)	After Lecture M (SD)	Before Lecture M (SD)	After Lecture M (SD)	Before Lecture M (SD)	After Lecture M (SD)
Facebook Multitasking	0.68 (0.24)	0.65 (0.27)	0.91 (0.15)	0.92 (0.15)	0.62 (0.21)	0.58 (0.26)
Multitasking Choice	0.67 (0.23)	0.65 (0.29)	0.87 (0.17)	0.91 (0.15)	0.56 (0.27)	0.59 (0.28)
No-Technology Control	0.77 (0.21)	0.74 (0.29)	0.87 (0.19)	0.86 (0.23)	0.63 (0.26)	0.71 (0.26)
Total	0.70 (0.23)	0.67 (0.28)	0.89 (0.17)	0.90 (0.17)	0.60 (0.25)	0.62 (0.27)

Table 6

Frequencies, Means, and Standard Deviations for the 18 Unique Themes Related to Multitasking Across Conditions

	Facebook Multitasking		Multitasking Choice		Overall	
	Frequency	M (SD)	Frequency	M (SD)	Frequency	M (SD)
M1. Split screen	5	1.20 (0.45)	1	6.00	6	2.00 (2.00)
M2. Half listening	2	2.50 (2.12)	4	3.25 (1.26)	6	3.00 (1.41)
M3. Pausing from lecture	3	1.67 (0.58)	3	1.67 (0.58)	6	1.67 (0.52)
M4. Dual task	5	1.40 (0.55)	2	1.50 (0.71)	7	1.43 (0.54)
M5. Other multitasking	3	3.67 (3.79)	10	5.40 (4.03)	13	5.00 (3.89)
M6. Fully engaged in non-relevant task	0		4	1.25 (0.50)	4	1.25 (0.50)
M7. Caught up with prompts	1	2.00	0		1	2.00
M8. Prompt or technology distracting	5	2.80 (2.49)	5	1.00 (0.00)	10	1.90 (1.91)
M9. Prompts less distracting over time	2	1.00 (0.00)	0	0	2	1.00 (0.00)
M10. Prompts not popping up	3	1.33 (0.58)	0	0	3	1.33 (0.58)
M11. Answers Prompt	7	2.71 (2.43)	0		7	2.71 (2.43)
M12. Not thinking about	3	1.00 (0.00)	0		3	1.00 (0.00)

Facebook yet						
M13. Late in initiating multitasking	2	2.00 (1.41)	1	1.00	3	1.67 (1.16)
M14. Finish lecture task before multitasking	3	1.00 (0.00)	2	1.50 (0.71)	5	1.20 (0.45)
M15. Attend rather than respond	6	1.00 (0.00)	3	1.00 (0.00)	9	1.00 (0.00)
M16. Thinking about how to respond	6	1.83 (0.98)	2	1.00 (0.00)	8	1.63 (0.92)
M17. Planning to multitask	0		2	1.00 (0.00)	2	1.00 (0.00)
M18. Easier to do messages because of familiarity with content	4	2.00 (1.41)	0	0	4	2.00 (1.41)
M19. Conflict	5	2.40 (1.34)	3	1.00 (0.00)	8	1.88 (1.25)

Table 7

Frequencies, Means, and Standard Deviations for the 15 Unique Themes Related to Learning Across Conditions

	Facebook Multitasking		Multitasking Choice		Overall	
	Frequency	M (SD)	Frequency	M (SD)	Frequency	M (SD)
L1. Trying to make notes make sense to learner	3	1.00 (0.00)	3	1.67 (0.58)	6	1.33 (0.52)
L2. Tie to prior knowledge	3	1.00 (0.00)	5	1.80 (1.10)	8	1.50 (0.93)
L3. Reflecting on content	7	3.14 (3.67)	6	3.00 (2.10)	13	3.08 (2.93)
L4. Use of strategy for content	2	1.00 (0.00)	0	0	2	1.00 (0.00)
L5. Planning to attend	0		3	1.00 (0.00)	3	1.00 (0.00)
L6. Monitoring missing information	6	3.00 (2.76)	5	1.80 (1.30)	11	2.45 (2.21)
L7. Comprehension monitoring	6	1.83 (0.98)	8	4.75 (3.11)	14	3.50 (2.79)
L8. Performance monitoring	1	1.00	4	1.75 (0.50)	5	1.60 (0.55)
L9. Selectivity of information	5	1.80 (1.10)	2	1.00 (0.00)	7	1.57 (0.98)
L10. Attending to examples	5	2.80 (1.64)	8	2.13 (1.46)	13	2.38 (1.50)
L11. Focusing	9	4.00 (1.50)	9	6.00 (4.50)	18	5.00 (3.41)
L12. Taking notes	10	5.70 (3.13)	10	6.70 (3.62)	20	6.20

						(3.33)
L13. Organizing notes	1	2.00	3	1.33 (0.58)	4	1.50 (0.58)
L14. Overwhelmed/fast delivery	2	1.00 (0.00)	2	1.00 (0.00)	4	1.00 (0.00)
L15. Bored	3	4.00 (1.00)	8	3.63 (2.33)	11	3.73 (2.01)

Table 8

Frequencies, Means, and Standard Deviations for the Don't Know and Irrelevant Responses Across Conditions

	Facebook Multitasking		Multitasking Choice		Overall	
	Frequency	M (SD)	Frequency	M (SD)	Frequency	M (SD)
DK	7	0.70 (1.64)	3	0.30 (0.67)	10	0.50 (1.24)
IR	1	0.10 (0.32)	6	0.60 (1.07)	7	0.35 (0.81)

Table 9

Frequencies, Means, and Standard Deviations for the Seven Aggregated Themes Related to Multitasking Across Conditions

	Facebook Multitasking		Multitasking Choice		Overall	
	Frequency	M (SD)	Frequency	M (SD)	Frequency	M (SD)
Many things	34	3.40 (2.72)	86	8.60 (6.74)	120	6.00 (5.67)
Prompts	41	4.10 (2.77)	5	0.50 (0.53)	46	2.30 (2.68)
Facebook not a priority	7	0.70 (1.25)	1	0.10 (0.32)	8	0.40 (0.94)
Lesson first	9	0.90 (0.74)	6	0.60 (0.70)	15	0.75 (0.72)
Multitasking thought	11	1.10 (1.20)	4	0.40 (0.70)	15	0.75 (1.02)
Easier to do messages because of familiarity with content	8	0.80 (1.32)	0		8	0.40 (099)
Conflict	12	1.20 (1.55)	3	0.30 (0.48)	15	0.75 (1.21)

Table 10

Frequencies, Means, and Standard Deviations for the Seven Aggregated Themes Related to Learning Across Conditions

	Facebook Multitasking		Multitasking Choice		Overall	
	Frequency	M (SD)	Frequency	M (SD)	Frequency	M (SD)
Involved with content	28	2.80 (3.39)	32	3.20 (3.36)	60	3.00 (3.29)
Planning and strategy	2	0.20 (0.42)	3	0.30 (0.48)	5	0.25 (0.44)
Monitoring	30	3.00 (3.23)	54	5.40 (3.84)	84	4.20 (3.66)
Critical information	9	0.90 (1.20)	2	0.20 (0.42)	11	0.55 (0.94)
Attending to lecture	50	5.00 (2.05)	71	7.10 (5.32)	121	6.05 (4.07)
Note-taking	59	5.90 (3.07)	71	7.10 (3.63)	130	6.50 (3.33)
Not following content	14	1.40 (2.17)	31	3.10 (2.51)	45	2.25 (2.45)

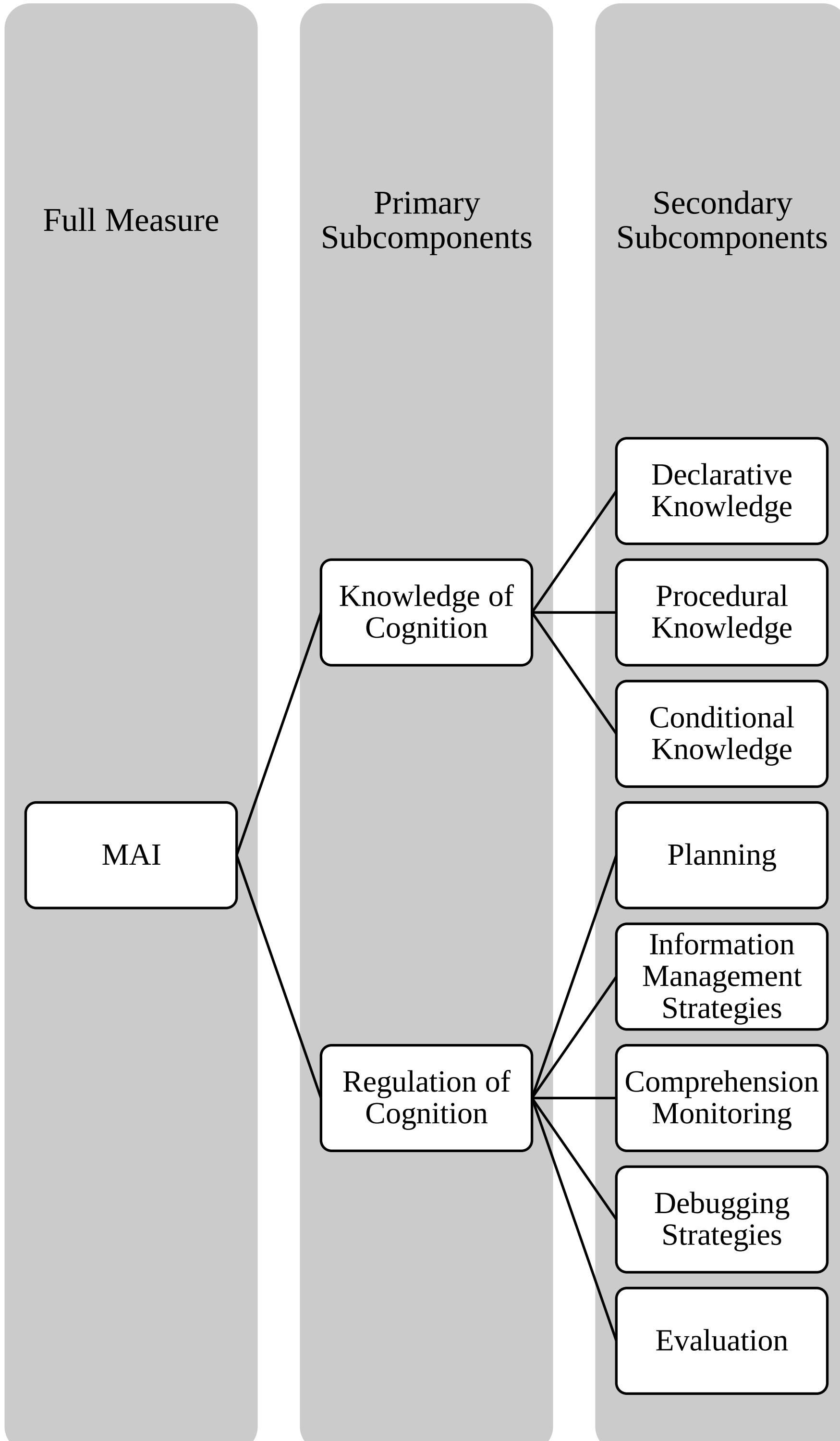


Figure 1. Metacognitive Awareness Inventory (MAI). This figure illustrates a breakdown of the MAI.

Appendices

Appendix A – Instructions Given to Participants in Each Condition

Facebook Multitasking Condition:

1. In this condition, you will be asked to use the chat function of Facebook to communicate with the RA. The RA's will send you a frined requeest. Please add him/her.
2. When the lecture starts, plese try to focus on it as much as possible and take lecture notes using Word. You can also opt to take paper-and-pencil-notes, in which case, please ask the RA for paper.
3. At one point during the lecture, the RA will contact you via Facebook. She will introduce herself and ask you to give her your CODE, which you were assigned. Please give her the code and NOT your student number. Then she will keep chatting with you, asking different questions about the learning material.
4. Please answer all questions before the lecture ends, but you can choose when it is the best time to reply.
5. You can also ask him/her questions about the lecture.
6. Please do not media multitask in any other way (i.e. Don't look at any photos on Facebook, or chat with anyone else on Facebook, don't text, don't search the internet, etc.) during this experiment.
7. Once the experiment has cocluded, "unfriend" the RA on your Facebook.

Multitasking Choice Condition:

1. In this condition you will be free to media multitask using a laptop and a cell-phone, in any way you choose (i.e. texting your friends, checking Facebook, tweeting, banking etc.). All you will be asked to do is to carry on as if there was no experiment going on, and you were in a regular classroom. Just do anything and everything that you would normally do with your media.
2. When the lecture starts, please try to focus on it as much as possible and take lecture notes using Word. You can also opt to take paper-and-pencil-notes, in which case, please ask the RA for paper.

Please note, your session will be video recorded. You will review the video with a TA later during this session, so you can explain to her why you chose to media multitask the way you did.

No-Technology Condition:

1. In this condition, you will not use any technologies.
2. Please DO NOT MEDIA MULTITASK in any way (i.e. Don't look at any photos on Facebook, or chat with anyone else on Facebook, don't text anyone else, don't search the internet, etc.) during this experiment.
3. Please pay your undivided attention to the lecture.
4. Once the lecture has ended, please email your notes to the research assistant [INSERT RESEARCH ASSISTANT NAME AND CONTACT INFORMATION HERE], with your ID code in the subject field. The researcher will not save or link your name or email address to your data.

Appendix B – Pre-Test Survey

1. Please enter your assigned ID code. Please make certain to type it in correctly.

2. What is your age?

3. What is your gender? Female Male Other

4. What is your Ethnic Background?

7. Considering all common technologies, i.e. laptops, smartphones, tablets, ipods,… How easy to use do you find them?

Not At All Easy
Not Very Easy
Somewhat Easy
Easy
Very Easy

Metacognitive Awareness Inventory (MAI): The following 52 items were assessed using the "True" of "False" scale.

19. I ask myself periodically if I am meeting my study goals.
20. I consider several alternatives to a problem before I answer.
21. I try to use strategies that have worked in the past.
22. I pace myself while learning in order to have enough time.
23. I understand my intellectual strengths and weaknesses.
24. I think about what I really need to learn before I begin a task.
25. I know how well I did once I finish a test.
26. I set specific goals before I begin a task.
27. I slow down when I encounter important information.
28. I know what kind of information is most important to learn.
29. I ask myself if I have considered all options when solving a problem.
30. I am good at organizing information.
31. I consciously focus my attention on important information.
32. I have a specific purpose for each strategy I use.
33. I learn best when I know something about the topic.
34. I know what the instructor expects me to learn.
35. I am good at remembering information.
36. I use different learning strategies depending on the situation.
37. I ask myself if there was an easier way to do things after I finish a task.
38. I have control over how well I learn.
39. I periodically review to help me understand important relationships.
40. I ask myself questions about the material before I begin.
41. I think of several ways to solve a problem and choose the best one.
42. I summarize what I've learned after I finish.
43. I ask others for help when I don't understand something.

44. I can motivate myself to learn when I need to.
45. I am aware of what strategies I use when I study.
46. I find myself analyzing the usefulness of strategies while I study.
47. I use my intellectual strengths to compensate for my weaknesses.
48. I focus on the meaning and significance of new information.
49. I create my own examples to make information more meaningful.
50. I am a good judge of how well I understand something.
51. I find myself using helpful learning strategies automatically.
52. I find myself pausing regularly to check my comprehension.
53. I know when each strategy I use will be most effective.
54. I ask myself how well I accomplished my goals once I'm finished.
55. I draw pictures or diagrams to help me understand while learning.
56. I ask myself if I have considered all options after I solve a problem.
57. I try to translate new information into my own words.
58. I change strategies when I fail to understand.
59. I use the organization structure of the text to help me learn.
60. I read instructions carefully before I begin a task.
61. I ask myself if what I'm reading is related to what I already know.
62. I reevaluate my assumptions when I get confused.
63. I organize my time to best accomplish my goals.
64. I learn more when I am interested in the topic.
65. I try to break studying down into smaller steps.
66. I focus on overall meaning rather than specifics.
67. I ask myself questions about how well I am doing while I am learning something new.
68. I ask myself if I learned as much as I could have once I finish a task.
69. I stop and go back over new information that is not clear.
70. I stop and reread when I get confused.

140. Today you are going to listen to a lecture, after which you will take a 20-item test. What mark out of 20 do you think you will get? (e.g. 15)

Appendix C – Post-Lecture Survey

1. What is your assigned ID Code? Please make certain to type it in correctly.

7. After listening to the lecture, and taking notes, what mark out of 20 do you think you will get? (e.g. 15)

Appendix D – Post-Test Survey

1. What is your assigned ID Code? Please make certain to type it in correctly.

Metacognitive Awareness Inventory [all items (38-89) are assessed as true or false]:

38. I ask myself periodically if I am meeting my study goals.
39. I consider several alternatives to a problem before I answer.
40. I try to use strategies that have worked in the past.
41. I pace myself while learning in order to have enough time.
42. I understand my intellectual strengths and weaknesses.
43. I think about what I really need to learn before I begin a task.
44. I know how well I did once I finish a test.
45. I set specific goals before I begin a task.
46. I slow down when I encounter important information.
47. I know what kind of information is most important to learn.
48. I ask myself if I have considered all options when solving a problem.
49. I am good at organizing information.
50. I consciously focus my attention on important information.
51. I have a specific purpose for each strategy I use.
52. I learn best when I know something about the topic.
53. I know what the instructor expects me to learn.
54. I am good at remembering information.
55. I use different learning strategies depending on the situation.
56. I ask myself if there was an easier way to do things after I finish a task.
57. I have control over how well I learn.
58. I periodically review to help me understand important relationships.
59. I ask myself questions about the material before I begin.
60. I think of several ways to solve a problem and choose the best one.
61. I summarize what I've learned after I finish.
62. I ask others for help when I don't understand something.
63. I can motivate myself to learn when I need to.
64. I am aware of what strategies I use when I study.
65. I find myself analyzing the usefulness of strategies while I study.
66. I use my intellectual strengths to compensate for my weaknesses.
67. I focus on the meaning and significance of new information.
68. I create my own examples to make information more meaningful.
69. I am a good judge of how well I understand something.
70. I find myself using helpful learning strategies automatically.
71. I find myself pausing regularly to check my comprehension.
72. I know when each strategy I use will be most effective.
73. I ask myself how well I accomplished my goals once I'm finished.
74. I draw pictures or diagrams to help me understand while learning.
75. I ask myself if I have considered all options after I solve a problem.
76. I try to translate new information into my own words.
77. I change strategies when I fail to understand.
78. I use the organization structure of the text to help me learn.

79. I read instructions carefully before I begin a task.
80. I ask myself if what I'm reading is related to what I already know.
81. I reevaluate my assumptions when I get confused.
82. I organize my time to best accomplish my goals.
83. I learn more when I am interested in the topic.
84. I try to break studying down into smaller steps.
85. I focus on overall meaning rather than specifics.
86. I ask myself questions about how well I am doing while I am learning something new.
87. I ask myself if I learned as much as I could have once I finish a task.
88. I stop and go back over new information that is not clear.
89. I stop and reread when I get confused.

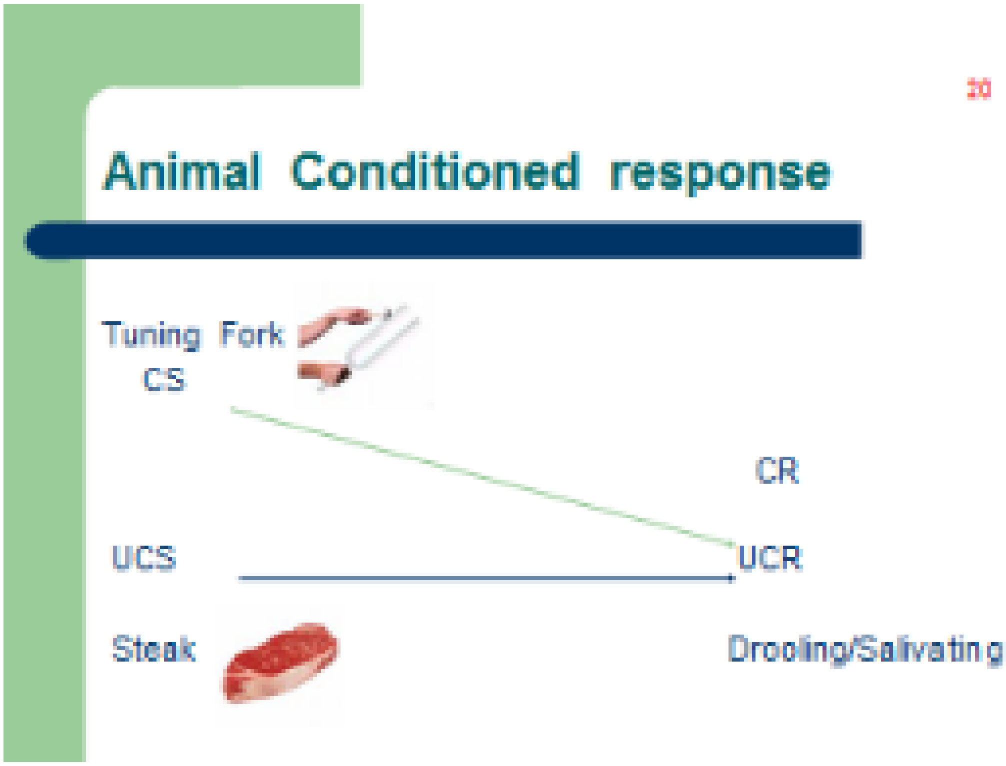
90. In your opinion, how capable are you at multitasking?

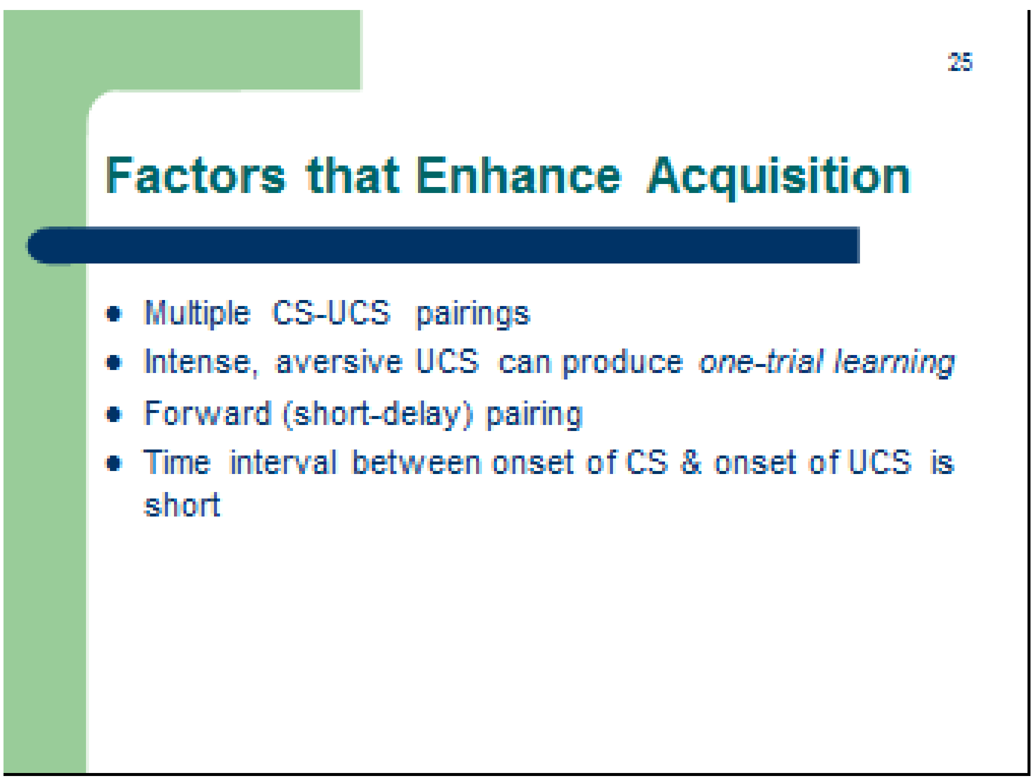
Not at all Capable
Not Capable
Somewhat Capable
Capable
Very Capable

91. In your opinion, when you media multitask in the classroom, how much does it affect your learning?

Not at all
Not very much
Somewhat
Quite a lot
Very much

Appendix E – Sample PowerPoint Lecture Slides





Appendix F – Messaging Protocol

Hello, I'm the RA for this course. Please complete the Pre-test survey now. Here's the URL. Thank you.
Pre-test Survey:

Slide 2:
Hey, I will now ask you a series of 10 questions. Please respond to them following the instructions for your condition, but do answer all of them before the end of the session. You can also ask me any clarifying questions if you want.

Slide 5:
Can you clarify the basic idea behind the rise of behaviourism for me?

Slide 8:
If you had to explain the basic premise for respondent conditioning simply what would you tell me?

Slide 11:
What is a conditioned response?

Slide 14:
Haha, this is cool. What is the unconditioned response to the lemon again?

Slide 17:
What happens to the neutral stimulus?

Slide 20:
In that steak and drool slide, what is the UCS here again?

Slide 23:
I missed the different types of UCS- CS pairings- can you give me one so I know where to look it up?

Slide 26:
What's the main idea behind Spontaneous Recovery?

Slide 29:
What is the purpose of higher order conditioning again?

Hello, you can complete the Post-lecture survey now. Here's the URL. Thank you.

Post-lecture Survey

Hello, you can complete the Post-test survey now. Here's the URL. Thank you.

Post-test Survey

Appendix G – The Interview Protocol

Talk Aloud Script Type 2

Note to RA: Always read the whole script, and dictate participant ID on the audio.

Now that we have video recorded your session, we would like to know why you made the multitasking decisions that you did. Specifically, we would like to know why you chose to multitask the way you did. As we play the video to you, please just try to think aloud about what you were thinking and doing at the time. From time to time we might ask you questions like: "I see that you receive a message, but did not respond to it right away. What was happening here?

Participant ID: ____

Slide 2

Example questions to ask:

1) What is happening at this point?
2) Can you tell me about what was going on through your mind at this point

These questions were asked for slides 5, 8, 11, 14, 17, 20, 23, 26, and 29

Appendix H - Original Interview Codes Related to Multitasking

M1 = Split Screen

- check back and forth for correct information
- more than one element on screen
- E.g., "I tried to split the screen"

M2 = Half Listening

- try to process audio lecture stream and read prompt (or do other task) at the same time
- E.g., "I was half listening while trying to respond to his questions."

M3 = Pausing from lecture, note-taking, and/or attending to look at prompt or do other things

- E.g., "received a message on Facebook asking what I had just learned about that slide. So immediately I did the same as earlier; <u>copied and pasted word for word from the slide</u> that I had copied down, sent it to you, and immediately went back to the slides and to the presentation"

M4 = Dual task (respond and take notes)

- E.g., "doing my own thing while I'm listening to the talk."

M5 = Other multitasking

- E.g., "I'm checking fantasy sports right now"

M6 = Fully engaged in the task that drew his/her attention away from lecture

- E.g., "Word stopped working, I don't know why. So then I just got confused and instead of paying attention, I was trying to fix the problem, but **I wasn't paying attention at all.**"

M7 = Caught up with prompts

- E.g., “I think I caught up to the Facebook questions a bit and I was focusing on what she was saying again”

M8 = Prompt or technology distracting

- E.g., “This Facebook message is annoying me, because I lost my attention on the slide, I put my attention on Facebook. And then my attention was on that even when I exited out of Facebook, I went straight back to focusing on Facebook while my eyes were even on the slide itself.”

M9 = Prompts less distracting over time

- E.g., “I think it was easier to respond to the questions.”

M10 = Prompts not popping up

- waiting for prompt
- E.g., “Why was she not messaging me? Like.”

M11 = Answers prompt

- E.g., “I was answering a question that she had asked me previously”

M12 = Not thinking about Facebook yet

- E.g., “I wasn’t really thinking about the Facebook yet.”

M13 = Late in initiating multitasking

- E.g., “I didn’t even realize that Facebook thing at that…I still didn’t even realize that we were supposed to be answering those Facebook questions. So then, I realized it, and I had like, uh, five questions.”

M14 = Finish note-taking or understanding lecture material before answering to prompt

- E.g., "whenever she switched the slides, I'd try to write the notes out and then once I was finished, I would go back to messages."

M15 = Attend rather than respond to messages (or multitask)

- E.g., ". I heard that you sent a message, but I thought, 'that can wait till the very end.'"

M16 = Thinking about how to respond

- E.g., "I think the R.A. just asked me a question and I was trying to answer it."

M17 = Planning to Multitask/ Thinking about Multitasking

- E.g., "I was also looking around at people, so I think that I was focused on thinking about what it would be like if I was on my phone during the presentation, if I was in another exercise. So, I was curious about that."

M18 = Easier to do messages because familiar with content

- E.g., "So it was a little easier to respond to messages when I got them because I knew what she was talking about"

M19 = Conflict

- perceived difficulty of multitasking
- needs that are counter to each other
  - need to respond versus need to attend or take notes
- E.g., "I kind of felt obligated to check my phone once in a while and stuff"

Appendix I - Original Interview Codes Related to Learning

L1 = Trying to make notes make sense to learner

- E.g., “creating my own examples in my head so I would better understand it“

L2 = Tie to prior knowledge

- E.g., “And I remember cause I learned that in high school and I was always confused by like which one was which.”

L3 = Reflecting on the content

- E.g., “They are talking about how you can teach certain things to certain organisms, so for example, fish. And how like an elephant can do a different pose, but like it couldn’t.”

L4 = Use of strategy for content

- E.g., “I was just picturing somebody doing that.”

L5 = Planning to take notes and/or attend/ Thinking about taking notes and/or attending

E.g.:

“Interviewer: Can you tell me about what was going on through your mind at this point?

Participant: That I should probably be paying attention.”

L6= Monitoring – that missing some content

- E.g., “And while I was doing that, she was talking about the next slide and I wasn’t writing that down. So I am pretty sure I missed some of that. So, I kept falling behind on each slide that was progressing.”

L7 = Comprehension Monitoring (new so more focus)

- E.g., “Yeah, as we got closer to the end, all I was thinking was how much knowledge that I actually retained in the tests.”

L8 = Performance monitoring

- E.g., “So, I was trying to figure out what was going on, I didn’t realize that the next slide was up”

L9 = Selectivity of information/trying to identify critical content

- E.g., “At this point, I am done writing the key points that I feel are necessary during the lecture “

L10 = Attending to example(s)

- E.g., “Dr. Wood was explaining the example with the tuning fork and the dog food”

L11 = Focusing on what is being said

- E.g., “just still listening, and engaged.”

L12 = Taking notes

- E.g., “I was taking notes”

L13 = Organize notes (formatting)

- E.g., “just trying to organize my notes”

L14 = Overwhelmed/fast delivery

- E.g., “I was getting a little overwhelmed because she was talking pretty fast”

L15 = Bored/losing focus/losing interest/tired

- E.g., “I got pretty bored like halfway through”

Appendix J - Other

DK = I don’t know

- E.g., “I’m not sure”

IR = Irrelevant

- E.g., “and I was thinking about getting my PREP Credits done with.”

Appendix K - Aggregated Interview Codes Related to Multitasking

Many things - More than one thing happening simultaneously

- Includes themes M1, M2, M3, M4, M5, and M6

All about prompts

- Includes themes M7, M8, M9, M10, and M11

Facebook not a priority

- Includes themes M12 and M13

Lesson first - Choice to attend to lesson before doing something else

- Includes themes M14 and M15

Multitasking thought - Planning or thinking about multitasking

- Includes themes M16 and M17

Easier to do messages because of familiarity with content

- Includes themes M18

Conflict - Perceived difficulty of multitasking

- Includes themes M19

Appendix L - Aggregated Interview Codes Related to Learning

Involved with content

- Includes themes L1, L2, and L3

Planning and strategy

- Includes themes L4 and L5

Monitoring

- Includes themes L6, L7, and L8

Critical information – Selectivity of information

- Includes themes L9

Attending to lecture

- Includes themes L10 and L11

Note-taking

- Includes themes L12 and L13

Not following content

- Includes themes L14 and L15